THE ROLE OF RIPARIAN BUFFERS IN WATER QUALITY IMPROVEMENT

A STUDY OF THE CHATTAHOOCHEE RIVER BASIN, GEORGIA

1985 – 2010

by Keith Adrian McCrary

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ACKNOWLEDGEMENTS

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Chapter 1
Introduction

Origin of Study

It is no secret that the absence of safe, affordable and sustainable drinking water remains one of the most important public health and development challenges in the twenty-first century United States. In 2000, I was an undergraduate student in a Geography program at a university in Berks County, Pennsylvania. At the time, I was in the heart of my curriculum and most of the students were environmentally conscious. One of the many projects I took on that semester was an environmental study at a small farm very close to the school.

Starting from the campus, a short drive through rolling hills of farms and silos eventually leads to the farm. The farm raises small livestock including several cows. There were approximately ten cows on the farm and what I observed in their grazing area was disturbing and eventually led to start this study. Any person could stand on the road at the end of the driveway and see that the cows were standing in water which was saturated with their own feces.

There was enough feces-saturated water in the yard to collect and form a very small stream. That small stream of water, made of a mixture of farm runoff and rain water, ran downhill to a ditch along the road. The water trickled down the road for about one half of a mile and drained into a nearby creek that serves as a source of drinking water for the local agricultural community. There was nothing to stop the cows from excreting into the collected rain water on the farm and eventually contaminating the drinking water supply. I

then wanted to study the potential benefits of a riparian buffer to clean drinking water and to improve the overall health of the natural environment.

About Riparian Buffers

A riparian buffer is simply a vegetated area that naturally grows alongside a river, stream, or creek that protects and separates the water from the adjacent land and the various types of activities it may be used for. Riparian buffers minimize stream bank erosion and flooding and they also improve water quality and the natural life that thrives in the environment. The length and the width of the buffer provide the desired functionality. Depending on the final goals for the water it will protect, the width of a riparian buffer often relates to the size of the water body in question.

The purposes and goals of a riparian buffer are particularly pertinent to this study. Riparian buffers are where shrubs, grass, and trees naturally grow. Trees within a riparian buffer will hang over the water body beneath it and cool the water by providing shade. This cooling increases oxygen levels and allows life to thrive. Furthermore, the roots of the plants on the stream banks stabilize the soil which reduces erosion. The soil filters and the plants absorb sediments and human-made chemicals before they reach a waterway that is potentially a source of drinking water. The goal of building a riparian buffer is to keep the environment clean and protect a source of drinking water.

Specifically, riparian buffers are defined as "the aquatic ecosystem and the portions of the adjacent terrestrial ecosystem that directly affect or are affected by the aquatic environment. This includes streams, rivers, lakes, and bays and their adjacent side channels, flood plain, and wetlands. In specific cases, the riparian area may also include a portion of

the hill slope that directly serves as streamside habitats for wildlife (www.usda.gov 2005). Riparian buffers are designed to filter runoff, provide canopy and shade, leaf food, nutrient uptake, and a natural habitat for organisms in the local ecosystem. When a buffer absorbs precipitation, the water is filtered and any contaminants present in the water are naturally removed by the soil. Riparian buffers have been observed to remove or reduce the levels of the contaminants chosen for this research. Dissolved oxygen was chosen to analyze the influence canopy cover has on its levels throughout the study period (www.epa.gov 2005).

The bark, wood and leaves from the vegetation that naturally grows in a buffer provide nutrients, leaf food, canopy cover and provides a naturally suitable environment for organisms of all kingdoms. The canopy cover increases levels of oxygen in the water, as shown in this research, and adds to the subsequent success of riparian buffers. Riparian buffer success is defined by goals set by a municipality or organization focusing on reduced stream bank erosion and fewer contaminants in drinking water (Durham 2004). Furthermore, the success of riparian buffers can also be found in the influence they have on improved drinking water standards, as set by the Environmental Protection Agency.

Research Area

The Chattahoochee River is one of the most important waterways in the Southeastern United States. The river is the keystone of the 8,770 square-mile Chattahoochee River Basin, which stretches into Alabama, Georgia, and Florida. Georgia in particular harbors a majority of the Chattahoochee River Basin. Originating in Union County, Georgia (Figure 1), the Chattahoochee River begins as a cold mountain stream and eventually grows into a major river with a median of 8,760 cubic feet of water per second.

Stretching approximately 434 miles in length, it flows south into Lake Seminole in Florida and eventually empties into the Gulf of Mexico. The river flows through several land types and uses including urban, suburban, forested, and agricultural land and is known for its everyday recreational use. The Chattahoochee River is the largest water resource in the entire state of Georgia supplying 70% of Atlanta's metropolitan population with drinking water. Its importance is not limited to just human consumption (Chattahoochee Riverway Project 2005).

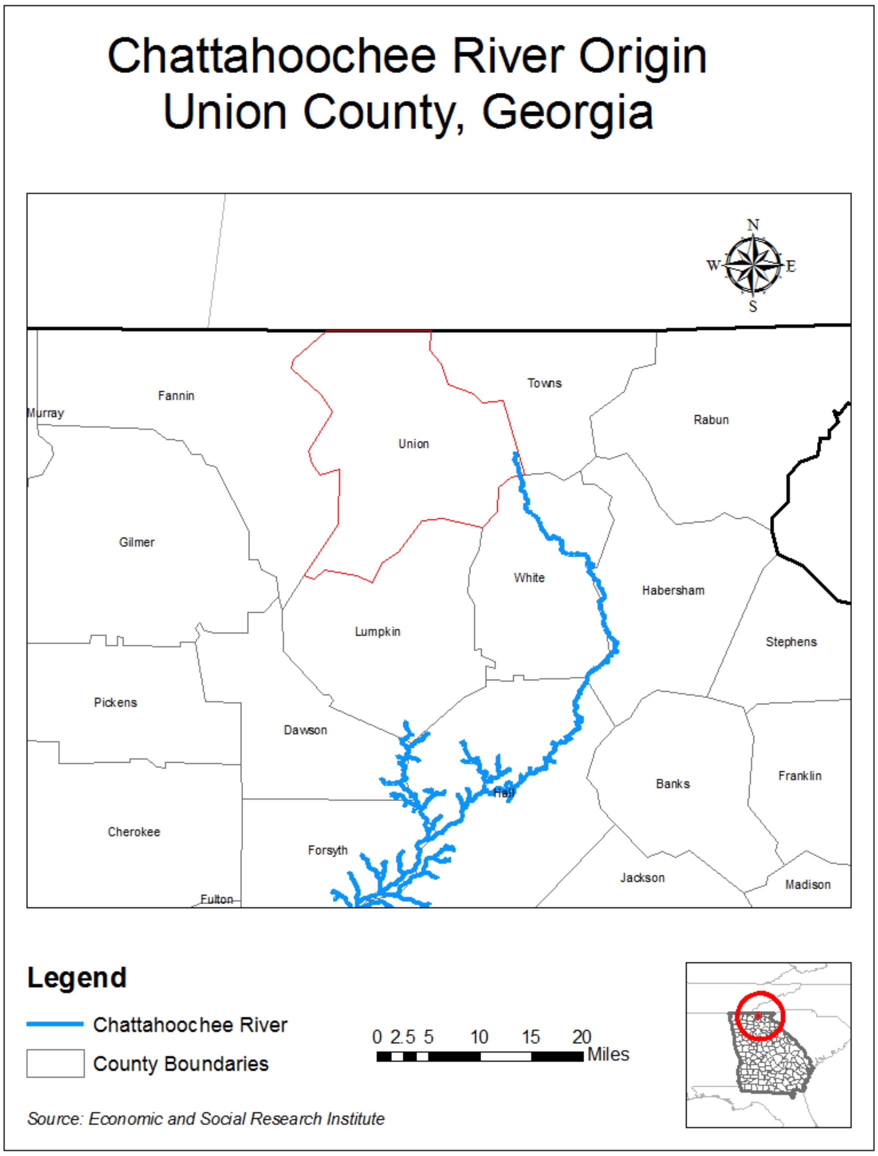

Figure 1: Origin of Chattahoochee River Basin, Union County, Georgia.

The Chattahoochee River and the surrounding wetlands include a large variety of wildlife and biodiversity. The basin is inhabited by 24 species of aquatic turtles, 37 species of salamanders and sirens, 30 species of frogs and toads, the American alligator, countless species of fish and is home to nine state threatened or endangered plant species (Georgia River Network 2005). The stability of the regional wildlife, along with the fact that the river supplies drinking water for millions of people, contributes to a statewide concern for the health of the river. There are six major land uses and land types in the Chattahoochee River Basin (Figure 2), with the majority being forested.

In the twentieth century, human beings developed a small but substantial percentage of the land within the basin in terms of landscape and land use and much of the river is used for hydroelectric power. Pollution is a subsequent result of this change within the basin. In order to effectively react to the increase of pollution, the state of Georgia passed the "Erosion and Sedimentation Act of 1975" which requires riparian buffers to be placed around all waterways in Georgia, including those within the Chattahoochee River Basin. In order to test the water quality in relation to the buffer installation, the United States Geologic Survey (USGS) has placed hundreds of test stations in waterways of all orders throughout the entire Chattahoochee River Basin (USGS 2005).

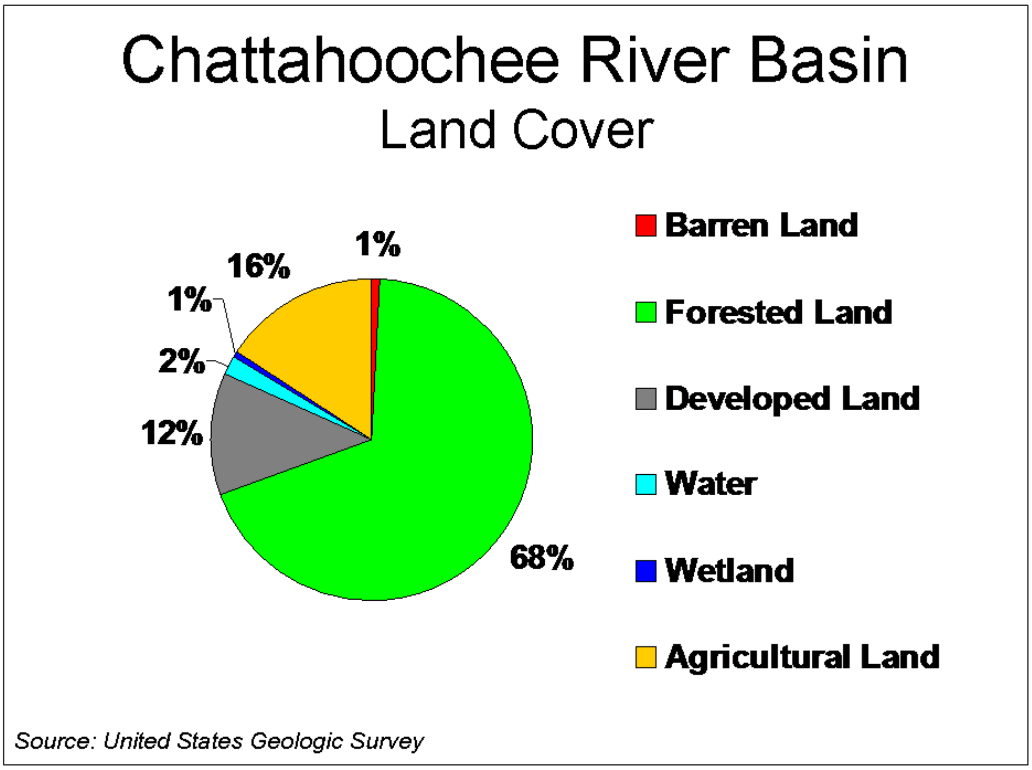

Figure 2: Land Use within Chattahoochee River Basin, published in 1998.

The study used Geographic Information Systems (GIS) to spatially locate all geographic features for visual investigation in ArcMap 9.3.1, including the geographic locations of the sampling stations used in the research (Figure 3). The layers included Georgia state waters, sampling station layer, and a Georgia county layer. The regions in pink are the counties that harbor the Chattahoochee River Basin. The blue line represents the Chattahoochee River and the points represent all twelve (USGS) sampling stations used for the research.

A GIS land use layer was used to analyze the locations of the sampling stations within certain land uses. The analysis of the land use layer showed that the sampling

stations located in urban and agricultural areas correlated with certain contaminants researched within the study. Sampling station #2331600, on the Chattahoochee River at Cornelia (Figure 3), was a suitable station to compare with the others since it was found upstream from Atlanta in a completely forested region. The station did not have any influence from agricultural or urban areas for close to three miles. This sampling station did not have the influence of excessive amounts of contaminant sources commonly found in other land-uses and land-types and the station was closest to complying with the EPA water quality standards throughout the entire twenty-five-year research period.

Station ID	Name	Geographic Location
#2337170	Chattahoochee River	Fairburn, Georgia
#2344040	Chattahoochee River	Steam Mill, Georgia
#2338500	Chattahoochee River	Franklin, Georgia
#2338720	Chattahoochee River	La Grange, Georgia
#2339500	Chattahoochee River	West Point, Georgia
#2337170	Chattahoochee River	Fairburn, Georgia
#2337000	Sweetwater Creek	Austell, Georgia
#2339720	Long Lane Creek	West Point, Georgia
#2337500	Snake Creek	Whitesburg, Georgia
#2336300	Peachtree Creek	Atlanta, Georgia
#2331600	Chattahoochee River	Cornelia, Georgia
#2336000	Chattahoochee River	Atlanta, Georgia

List of sampling stations for research.

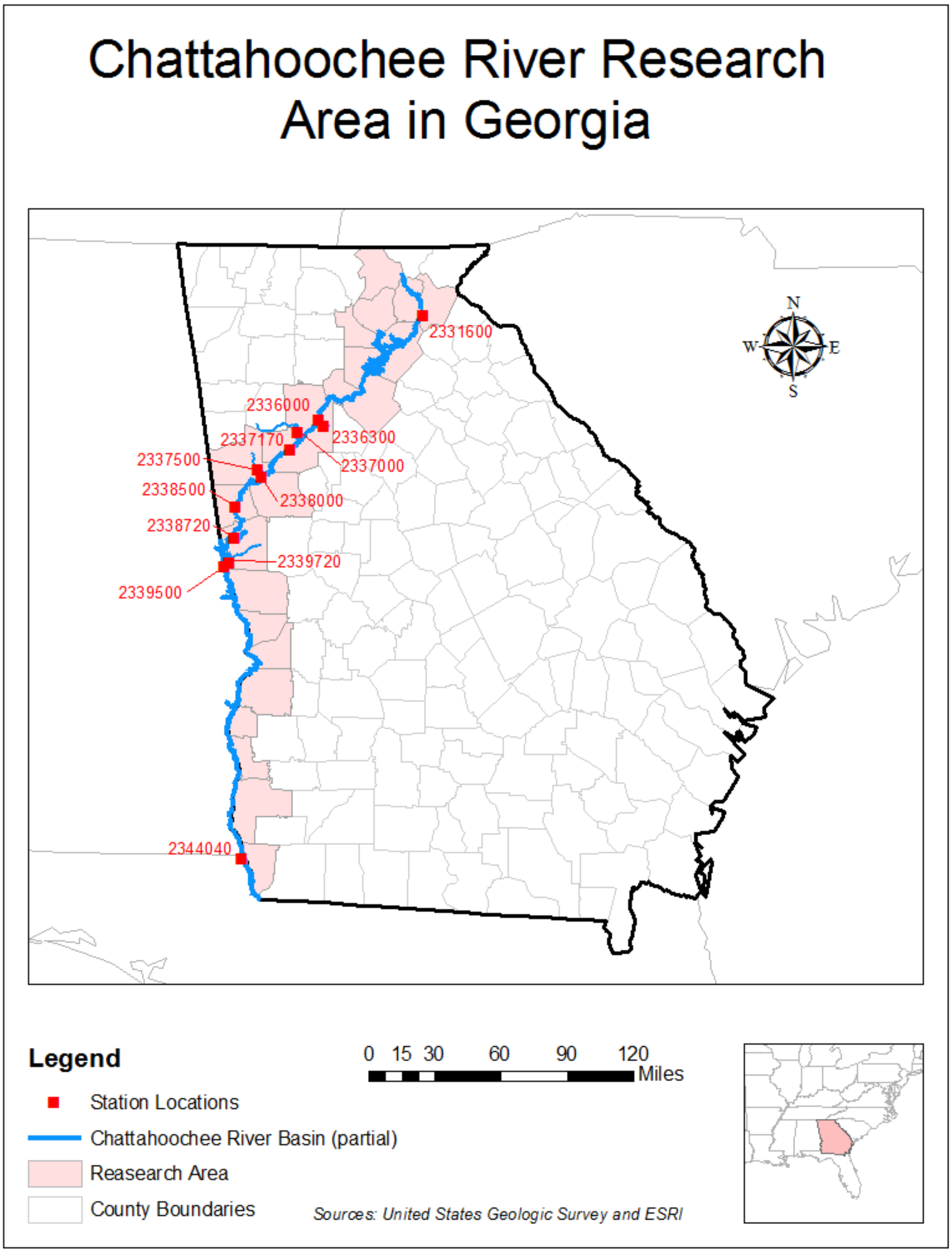

Figure 3: Map of Research Area, Chattahoochee River Basin, Georgia.

The Water Quality Variables

The study measures four water variables which are factors to determine the effectiveness of the riparian buffers as a method to cleaning drinking water. Dissolved oxygen analysis measures the amount of gaseous oxygen dissolved in an aqueous solution. Waterways create and consume oxygen and they gain oxygen from the atmosphere and from plants through the process of photosynthesis. Running water, in streams and rivers, dissolves more oxygen than still water, such as that in a reservoir. Respiration by aquatic animals, decomposition, and various chemical reactions consume oxygen. Oxygen is measured in its dissolved form as dissolved oxygen. If more oxygen is consumed than is produced, dissolved oxygen levels will decrease and more sensitive animals may move away, become weak, or die (www.epa.gov 2011).

Phosphorus is a multivalent nonmetal and a mineral that occurs typically as inorganic phosphate rocks. Phosphorus is an essential nutrient for the plants and animals that live in the aquatic food web. Since phosphorus is a rare nutrient in fresh waters, even a slight increase in phosphorus can start a whole chain of undesirable events including accelerated plant growth, increased algae, lower levels of dissolved oxygen, and the death of countless aquatic animals. Phosphorus sources include soil and rocks, wastewater treatment plants, runoff from fertilized lawns and cropland, failing septic systems, runoff from animal manure storage areas, disturbed land areas, drained wetlands, water treatment, and commercial cleaning preparations (www.epa.gov 2011). Phosphorus is a general protoplasmic poison that, when consumed, can cause cardiac, hepatic, renal, and multiorgan failure. The safest way to deal with this lethal substance is prevention.

Nitrites are a major constituent of fertilizers that have been used for many years for agricultural use and in lawn treatments. Without the addition of Nitrites, crops would deplete nitrogen from the soil. The potential for nitrite consumption is higher when private wells become contaminated from feed lot, agricultural runoff, and contaminated groundwater (www.epa.gov 2011). Infants younger than six months of age who drink water containing nitrite in excess of the maximum contaminant level (MCL) could become seriously ill and, if left untreated, may die. Symptoms include shortness of breath and blue baby syndrome (www.epa.gov 2011).

Fecal coliform is a rod-shaped, non-sporulating bacterium whose presence indicates that water may be contaminated by human or animal excrement. Fecal coliform bacteria can enter rivers through direct discharge of waste from mammals and birds, from agricultural and storm runoff, and human sewage. The human consumption of fecal coliform can cause diarrhea, cramps, nausea, headaches, waterborne diseases are giardiasis and cryptosporidiosis; both cause intestinal illness, and hemolytic uremic syndrome, which is a serious kidney condition (Vermont Department of Health 2005).

Previous Studies in Research Area

There have been several studies of water quality within the Chattahoochee River Basin. Past research show a strong focus on water quality in the 1980's that brought attention to the sources of water pollution. The studies that brought these issues into light also offered possible solutions.

USGS teams conducted many of the studies using their own data and analysis methods in order to bring these issues to the forefront conducted many of the studies. Hippe et al. (1998) studied the change of nutrient levels in surface water quality due to change in land use at the headwaters of the Chattahoochee River Basin. The study indicates that land disturbance is due to the growth of the Atlanta metropolitan area in recent decades. Increased land disturbance and runoff has helped increase erosion and sedimentation. The runoff in particular is blamed for an increase of pesticides and toxic chemicals found directly in the drinking water (Hippe et al. 1998).

Gregory and Frick (2000) analyzed fecal-coliform bacteria in the Chattahoochee River Basin between 1994 and 1995. Specifically, the study was done in the Metropolitan Atlanta region where the largest populations of people reside within the basin. The findings of the research include colonies of fecal-coliform bacteria around Buford Dam, near Lake Sidney Lanier, where many samples were found to have exceeded the United States Environmental Protection Agency’s water quality standards. Furthermore high concentrations of fecal-coliform were found in runoff from parking lots, lawns, and overflowed sewers. The origin of the bacteria is from both human and non-human sources (Gregory and Frick 2000).

Hartel et al. (2004) examined E. Coli in the Atlanta region in the Chattahoochee River Basin in 2000. The research looked at E. Coli amounts at twelve sampling stations in the Chattahoochee River and several tributaries. The research concluded that both baseflow and stormflow conditions in certain land-use patterns are responsible for increased amounts of E. Coli. Past research in the Chattahoochee River Basin has a focus on the Metropolitan Atlanta region for its mix of land-uses and land-types and the contaminants found in the region (Hartel et al. 2004). Water quality is a concern in this area because of the large population consuming this water and analysis shows an effort needs to be made to ensure safe drinking water.

Assumptions of Study

There are assumptions about several aspects of this research. There are assumptions about local and state regulations and legislation in terms of assistance in water quality improvement. There are assumptions about local land use and its role in water quality. Furthermore, there are assumptions about riparian buffers as a method of cleaning state waters.

The first assumption of the research is that no other clean water regulations influence the results of this study. The study takes into account that although there may be other water cleaning efforts in the Chattahoochee River Basin, this research only recognizes the efforts of the riparian buffers established from the Erosion and Sedimentation Act of 1975. A second assumption of this research is that riparian buffers are being used and regulated and the legislation is being followed as written within the Erosion and Sedimentation Act of 1975. Although some land uses have not changed due to this

particular act, there is an assumption in this research that there is little or no development within the riparian boundaries after 1989. The assumed characteristic of the riparian buffers is vegetation, with the exception of existing developments before the 1989 buffer installation.

The Project Objective

Past water quality research has shown evidence of continuing fluctuations in water quality due to several factors. There is an emphasis on the role of improved methods of cleansing drinking water by wastewater treatment plants and the building of riparian buffers. The objective of this study is to investigate the effectiveness of the installation of riparian buffers in 1989 and their role in filtering contaminants out of the water that wildlife and millions of people alike depend on. Data collected by the United States Geologic Survey between 1985 and 2010 will be used to analyze the change in water quality variable amounts in the basin. The length of the study period was chosen because it is suggested that the maximum efficiency of a riparian buffer is measured between ten and fifteen years (Iowa State University 2005). It is suggested that it takes over ten years for the subsequent vegetation to occupy the area and for the soil to reach its optimum state. Therefore the twenty-five-year study period was adopted for this research.

The 12 USGS sampling stations used in the research are geographically located throughout the watershed. The data was analyzed in charts and maps and overall water quality was assessed. The research hypothesis is that there will be a significant decrease of the contaminants phosphorus, nitrites and fecal coliform bacteria and an increase of

dissolved oxygen after the installation of the riparian buffers throughout the twenty-five-year study period.

Chapter 2
The Literature Review

A literature review influenced the method in which the Chattahoochee River Basin research was conducted. The literature reviewed for the Chattahoochee River Basin study analyzed riparian buffers, research methodology, statistical methods, and water quality variables. The literature assessed for the Chattahoochee River Basin research included few theoretical studies. The nature of riparian buffer research is empirical and it relies on observations and experimentations.

The Chattahoochee River Basin research reviewed literature that included an empirical approach. The research "Planted Riparian Buffer Zones in New Zealand: Do They Live Up to Expectations?" (Parkyn et al. 2003) analyzed how riparian vegetation improved water quality. Many studies do not follow up on projected water quality improvement, but this project studied nine riparian buffers that were installed in the Waikato Region in New Zealand between two and twenty-four years before this study. The focus of the study was to investigate if riparian buffers improved local water quality. The researchers investigated both the variability in the water quality levels and the degree of success of the riparian buffers. The purpose of the project was to study the degree of change in the water quality variables.

The research factors include length of time that the riparian buffer had existed, the width of the buffer, and several water quality variables such as water clarity, fecal bacteria, temperature, E.Coli, dissolved phosphorus, and total nitrogen. The regions with riparian buffers were compared to the control places, which were without riparian buffers. In

general, there were decreases in water quality variables and an increase in water clarity at those study areas with riparian vegetation. The results were analyzed in graphs and charts and could influence future investigation. The larger buffer zones had the greatest improvement in water quality variables. The researchers focused on the expectation of riparian buffers to achieve environmentally- oriented goals (Parkyn et al. 2003).

Ducros et al. (2003) discusses the United Kingdom's government wanting to improve their water quality in 1994. The empirical study analyzed riparian buffers as a method of improving water quality, controlling sediment levels and controlling erosion. As in the Parkyn et al. (2003) study, the force behind the research was that riparian buffers are built and are assumed to improve stream bank strength back to their natural condition due to excessive erosion. In 1997, researchers in England developed a method of assessing the riparian buffers they had built near agricultural catchments several years earlier (Ducros et al. 2003).

A plan was prepared to create the 'Buffer Zone Inventory and Evaluation Form' (BZIEF) as a quick and organized pencil-and-paper method of evaluating the effectiveness of riparian buffers. The form used a point system and was designed to analyze the condition of stream banks, streambeds, and overall water quality. There were a variety of buffer zone effectiveness objectives and they wanted a simple method of evaluating both water quality and the condition of the physical stream banks. The evaluation of the buffers yields very positive results. Benefits of the riparian buffers included a high quality aquatic habitat, little or no erosion, and overall general higher quality stream bank strength. The advantage of an evaluation system like BZIEF is the low cost and little time it takes to do a relatively thorough analysis of the stream banks within riparian buffers (Ducros et al. 2003).

Aschengrau et al. (1993) had an empirical approach to the relationship between late adverse pregnancy outcomes with amounts of contaminant variables in public drinking water. The study analyzed records from the Brigham and Women's Hospital in Massachusetts between 1977 and 1980 and studied stillbirth, congenital anomaly and neonatal death. The research focused on twenty-four water quality variables and broke down the adverse outcomes into three ordinal categories, which were one or more major malformations, minor malformations and normal variants. Specifically, chlorine, lead, potassium, silver and fluoride were all highlighted as variables that were known to cause pregnancy problems in past studies. The levels of each water quality variable was measured and compared to each group of pregnancy outcomes using the hospital records. With the exception of lead, the level for each water quality variable was under the maximum contaminant level, as set by the EPA. The study found an increase between ear, face and neck anomalies and the intake of silver and a decrease of the same anomalies with the intake of potassium. The research shows no stable statistical significance or stable correlations and researchers suggested a more thorough analysis. The article mentions the statistical instability of the study and the figures were adjusted to fit the overall scope of the study. There were minor, insignificant relationships but they deserve further study and attention (Aschengrau et al. 1993).

The empirical study "Effects of Riparian Forest Removal on Fish Assemblages in Southern Appalachian Streams" (Jones et al. 1999) used GIS to research the effects of riparian vegetation on fish species and total fish population. The study area is the Little Tennessee River drainage basin in Macon County, North Carolina and Rabun County, Georgia. They compare both streams with riparian vegetation against streams without

riparian vegetation. For the streams with riparian vegetation, they compared and measured riparian buffer width and length and total population of certain fish species within the corridor. Over the years, the local people have created agricultural areas along streams that over time have degraded banks, modified the chemical composition of the soil, and littered the water with pesticides and sedimentation.

ArcInfo and satellite imagery were used to help choose the twelve study sites. Among other variables, water temperature, conductivity and bank cross-section were recorded at each site. Once the fieldwork was completed, the statistical analysis was done. Regression and correlation analyses and Pearson's correlation coefficients were used to study fish population in relation to the water quality and the results showed that overall fish population decreased as non-vegetated riparian patch length increased. This is due in part to fish species thriving in canopy cover and sensitivity to lesser water quality in regions without riparian vegetation. Although there were several tests and discussions concerning the benefits riparian vegetation, the results showed that even a moderate degree of habitat disturbance could change the living and breeding patterns of fish. A limitation of the study is the location of the sampling stations as they should have been evenly distributed throughout the entire watershed but were not. Furthermore, the sample size of ten is too small to accurately represent an entire watershed (Jones et al. 1999).

The literature focused on the use of riparian buffers to achieve an improvement of water quality, as in this Chattahoochee River Basin research. The literature research included an analysis of several locations throughout a basin or watershed. These locations include land parcels and the sampling stations that collected the necessary data for research. This Chattahoochee River Basin research used twelve

sampling stations points, and this number of stations correlates with similar studies as a small representation of the basin. The literature also showed several studies performing water quality tests, within riparian buffer zones, in major drinking water sources. The importance of drinking water research is found in this Chattahoochee River Basin study as the river itself supplies much of the metropolitan Atlanta with drinking water.

There was a wide variety of water quality variables found in the literature. This Chattahoochee River Basin research used four water quality variables—phosphorus, nitrites, fecal coliform, and dissolved oxygen—to test for water quality. Some of the literature studied more than four while others researched less. The reviewed literature displayed data in maps and charts. Some of the literature used GIS, as in this Chattahoochee River Basin research, and the display of annual water quality variable trends in line charts. This Chattahoochee River Basin research used several line charts to analyze the trends and was later tested for statistical significance. The use of tests for statistical significance was found in a majority of the literature. Other statistical methods were employed in the literature. This Chattahoochee River Basin research used annual means for a change in water quality due to riparian buffers and tests for statistical significance of the change.

Chapter 3
The Georgia Erosion and Sedimentation Act of 1975

The Georgia Erosion and Sedimentation Act of 1975 was passed to control erosion and to control sediments, contaminants, and nutrients from polluting the water. The Act was passed using "Best Management Practices" to control land-disturbing activities (www.georgia.gov 2005). The premise of the document was to use riparian buffer zones to meet these statewide goals. The Act was passed on April 24, 1975, the riparian buffers were implemented in 1989 (Jan Sammons from the Georgia Department of Natural Resources Environmental Protection Division. January 18, 2005). The law is to be followed by any entity that borders any waterway in the state disregarding prior ownership to owned land, and section 15a of the act states "No land disturbing activities shall be conducted within a buffer and a buffer shall remain in its natural, undisturbed state of vegetation until all land disturbing activities on the construction site are completed" (www.georgia.gov 2005).

The Georgia Erosion and Sedimentation Act of 1975 define several terms that are used many times throughout the document. The document defines a buffer as "the area of land immediately adjacent to the banks of state waters in its natural state of vegetation, which facilitates the protection of water quality and aquatic habitat" (www.georgia.gov 2005). The Act does not require the building of riparian buffers by planting vegetation, rather to let the buffer zone exist in its natural state. The Act requires twenty-five foot riparian buffer zones on all waterways and fifty-foot riparian buffers around waters classified as "trout streams" (www.georgia.gov 2005).

The Georgia Erosion and Sedimentation Act of 1975 was implemented in 1989 and it is a state law. The Act requires counties to direct and oversee that the law is being followed and to make the proper exceptions. Each county has its own set of erosion and sedimentation requirements that all municipalities are required to follow. Each of the seven counties involved in this research have their laws posted online and each refer to the Georgia Erosion and Sedimentation Act of 1975 as its guide with few exceptions.

The Act grants any violators with five days to correct the violation. If the violation is not corrected to a passable condition, the act states that “there shall be a minimum penalty of two hundred fifty dollars ($250.00) per day for each violation involving the construction of a single family dwelling by or under contract with the owner for his or her own occupancy” (www.georgia.gov 2005). Furthermore, the act states that “there shall be a minimum penalty of one thousand dollars ($1,000.00) per day for each violation involving land disturbing activities other than as provided in subsection (D)(2)(a) of this section” (www.georgia.gov 2005).

The Act does allow exceptions that are reviewed by the director, who is defined by the Georgia Erosion and Sedimentation Act of 1975 as “the director of the Environmental Protection Division of the Department of Natural Resources” (www.georgia.gov 2005). The director is in charge of overseeing the act at the county or municipal level. If any entity wishes to engage in any activity that violate any part of the act, they can apply for an exemption by filling out the “Application For A Twenty-Five Foot Vegetative Buffer Encroachment”, which is a four-page form that requires all knowledge of intentions within the project. Exceptions to The Act include, but are not limited to, surface mining, quarry activities, forestry land management practices and minor residential land-disturbing

activities such as home gardens and landscaping. The Act also exempts several agricultural operations.

Chapter 4
The Methodology

This research analyzes the influence and effectiveness of riparian buffers with an investigation of changes in water quality variables over the twenty-five-year study period. The installation of riparian buffers in the state of Georgia in 1989 provided the temporal boundary in the research between a period before and the affects after implementation of the buffers. The annual change in the water quality variables is analyzed in a paired samples t-test, Mann-Whitney U-Test, and in several line charts that show this change before and after 1989.

GIS

GIS was used for the purpose of making the geographical area known and to show the study area in terms of land use. The USGS provided several layers of data used for the research. Each layer was imported into Arc Map 9.3.1 for spatial analysis. The base layer, released by the United States Census Bureau in 2010, is a polygon layer that showed all the counties that harbor any waterway included in the Chattahoochee River Basin. The second layer used is a line layer that represents the Chattahoochee River basin. The third layer is a point layer representing the locations of each sampling station. Each layer was imported into ArcMap 9.3.1 for visual analysis for the benefit of the overall research.

The GIS datasets were made available by the USGS as zip files for each hydrological unit. The zip file provided several geographic data layers representing the Chattahoochee River Basin and a text document with all metadata and additional information. A land-type layer, created during the 1970’s and 1980’s and published in

1998, was added to provide possible reasons for certain water quality variable origins and quantities. This layer includes forested, agricultural, water, and urban land types and land uses. These variables within the land use layer were analyzed in relation to the locations of each sampling station. All layers used in this study are ‘snapshots’ of a certain time period.

GIS was used to show land use and land types of the areas surrounding the twelve sampling stations. Figures 4 through 15 show the geographic location of the twelve sampling stations and their surrounding land use and land types as provided by the USGS. The land uses include urban, agricultural, forestland, water, wetland, and barren land. Several of the sampling stations used in this research were found within agricultural, forested, barren land, or urban land types.

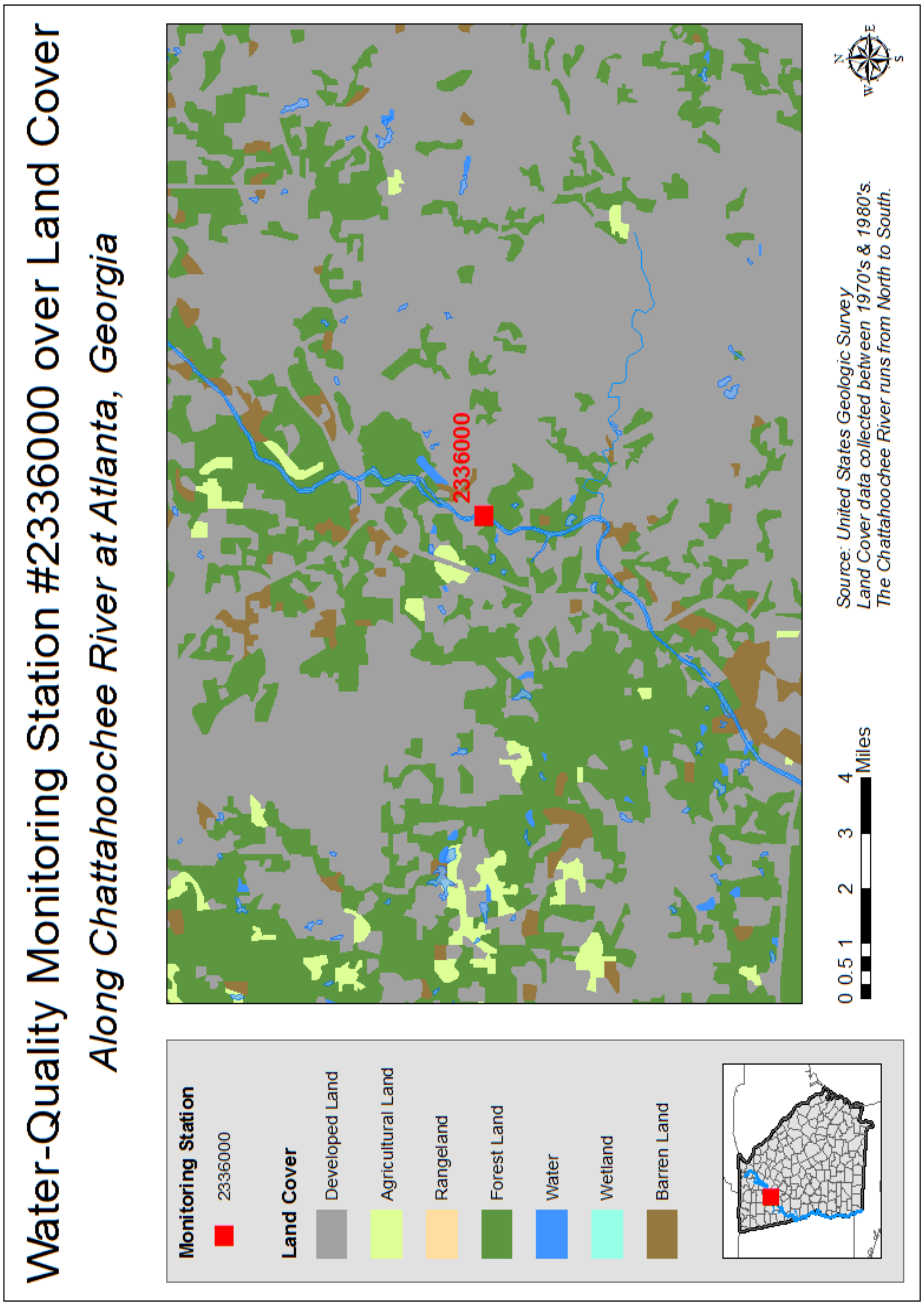

Figure 4: Sampling Station along Chattahoochee River at Atlanta, GA.

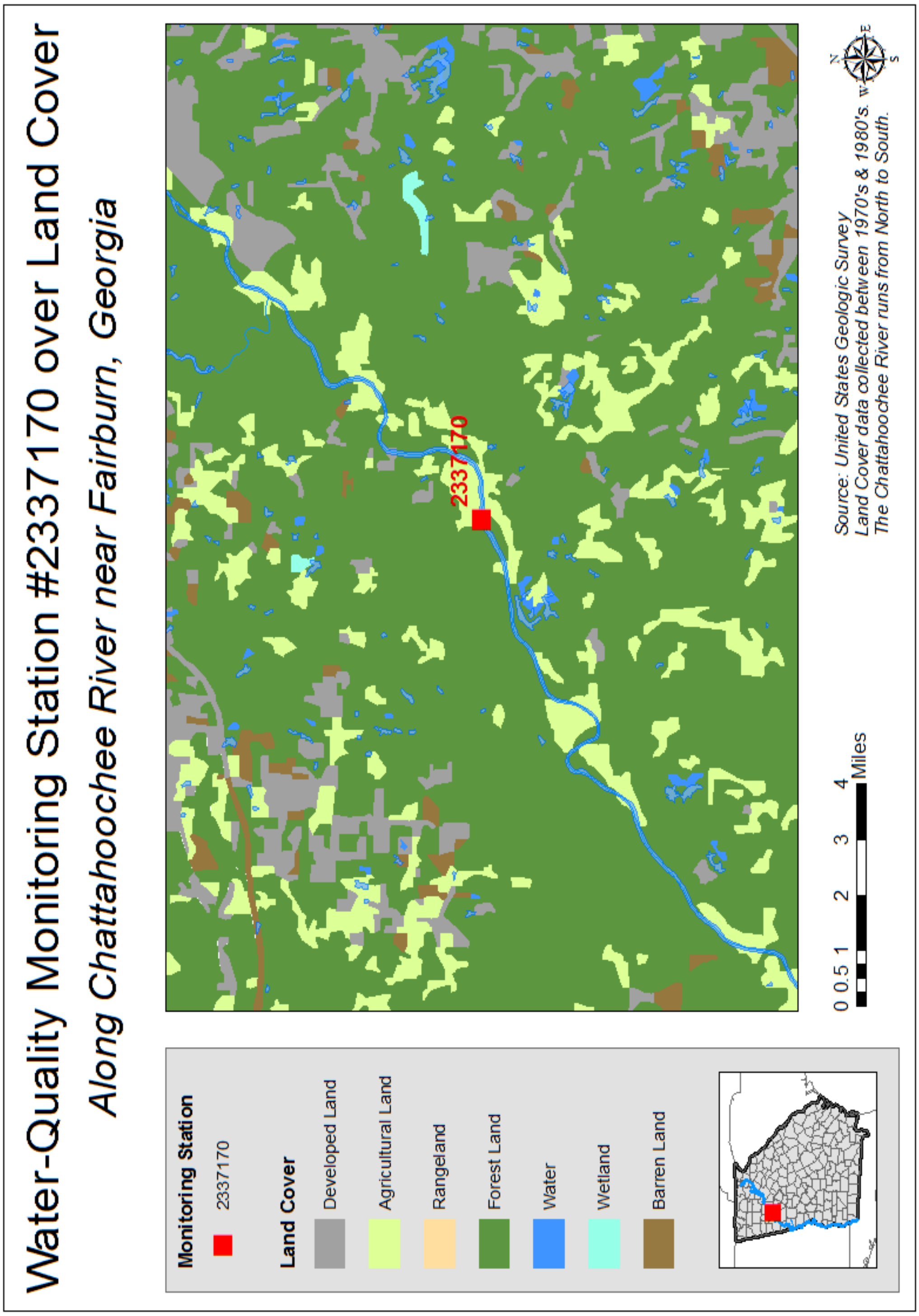

Figure 5: Sampling Station along Chattahoochee River at Fairburn, GA.

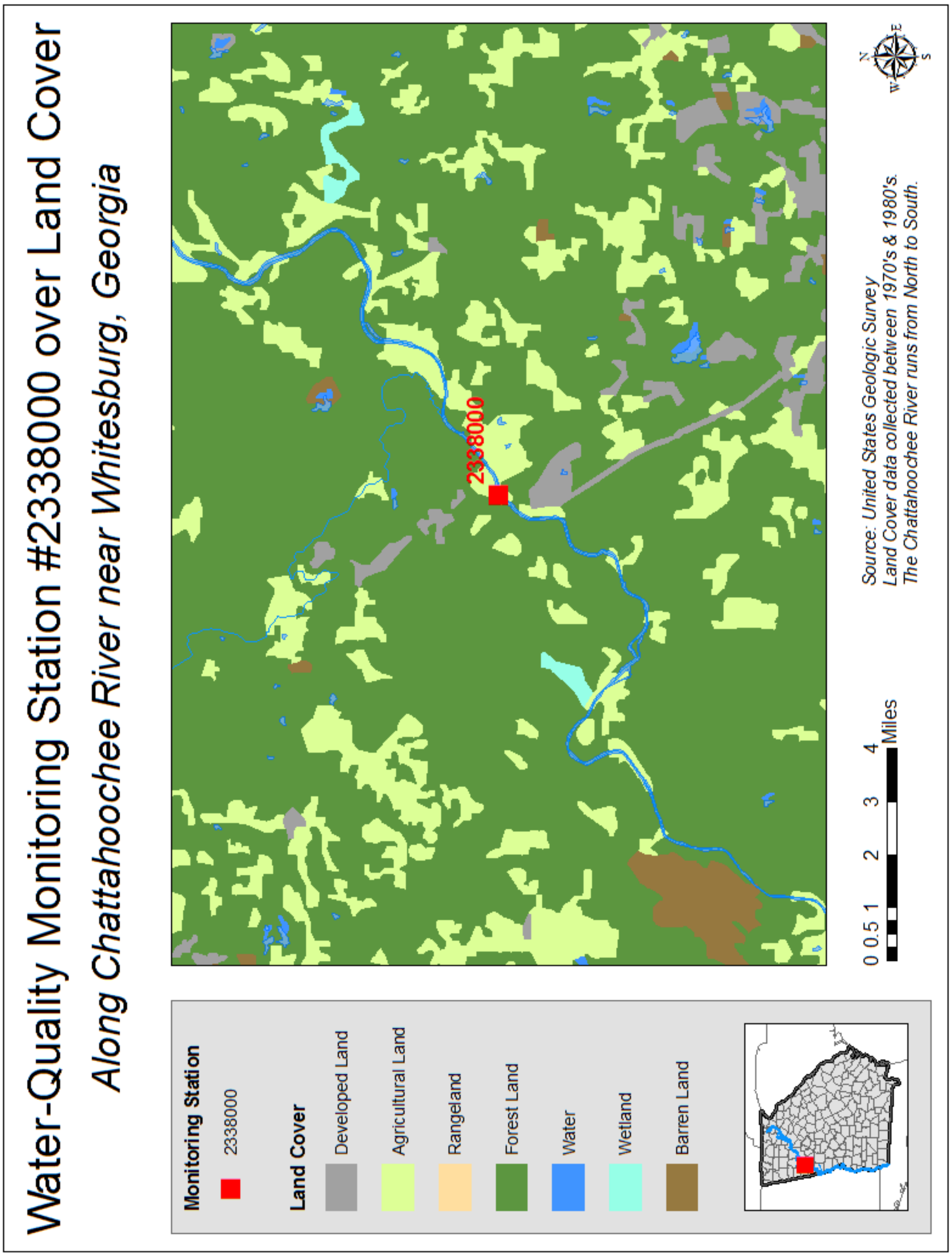

Figure 6: Sampling Station along Chattahoochee River at Whitesburg, GA.

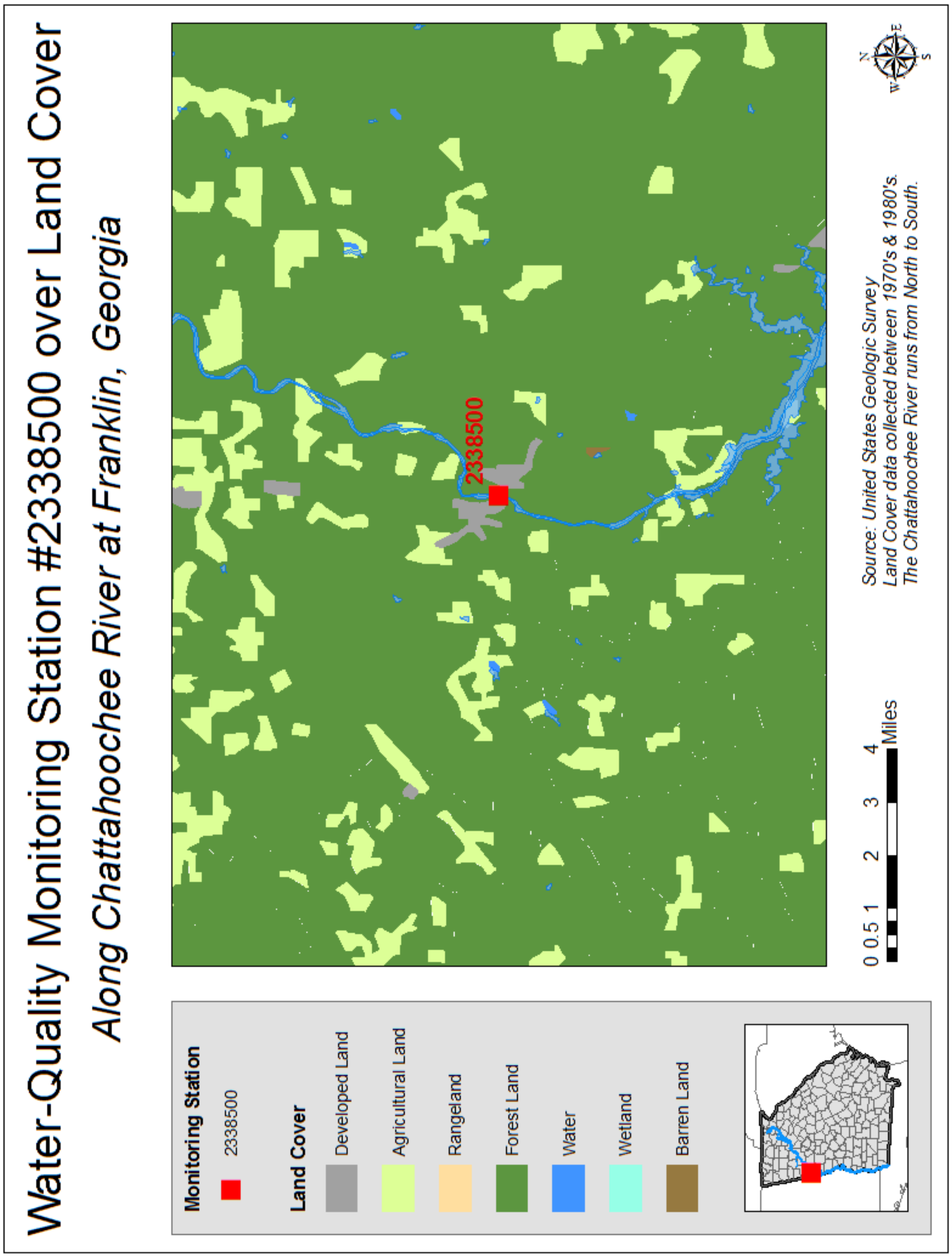

Figure 7: Sampling Station along Chattahoochee River at Franklin, GA.

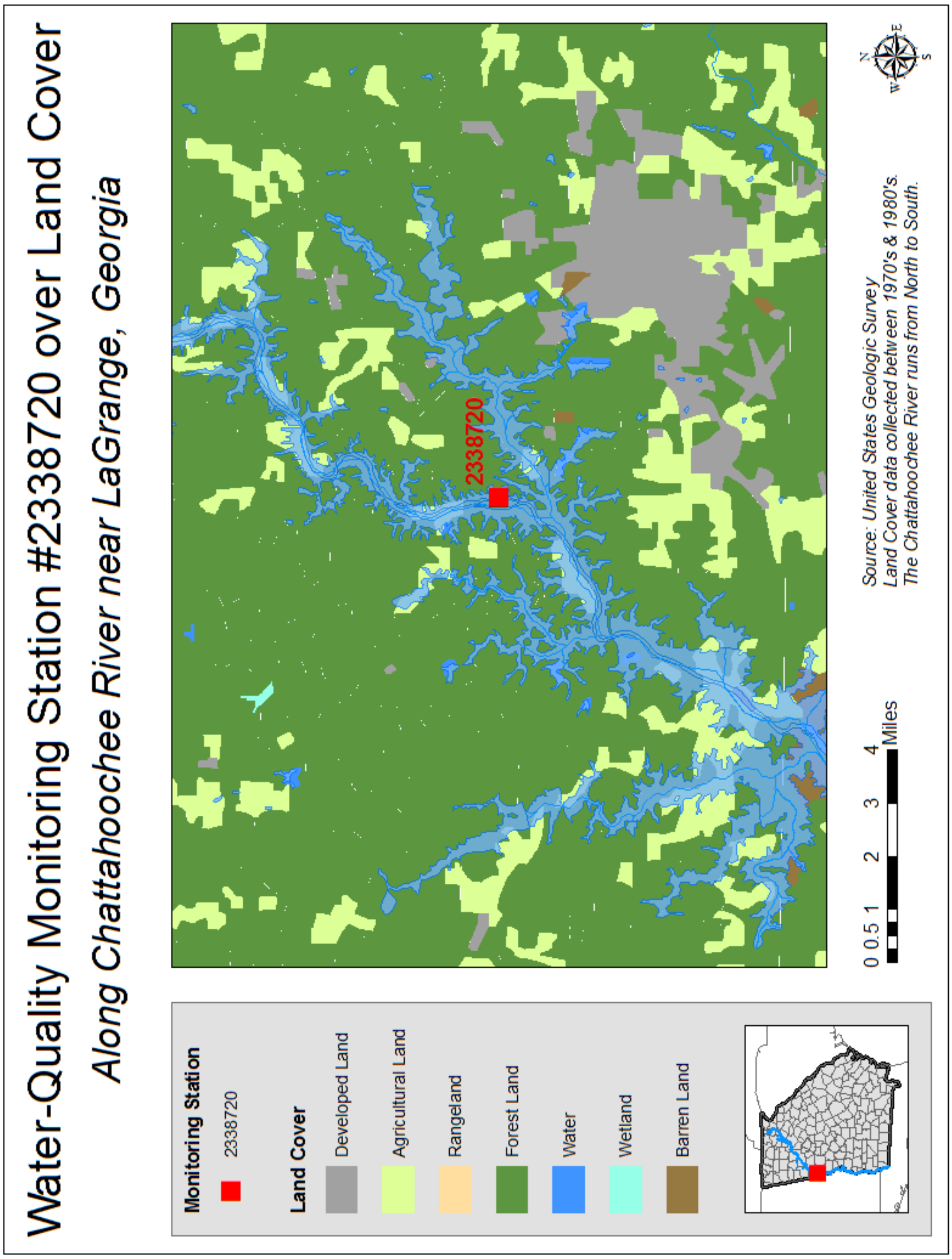

Figure 8: Sampling Station along Chattahoochee River at LaGrange, GA.

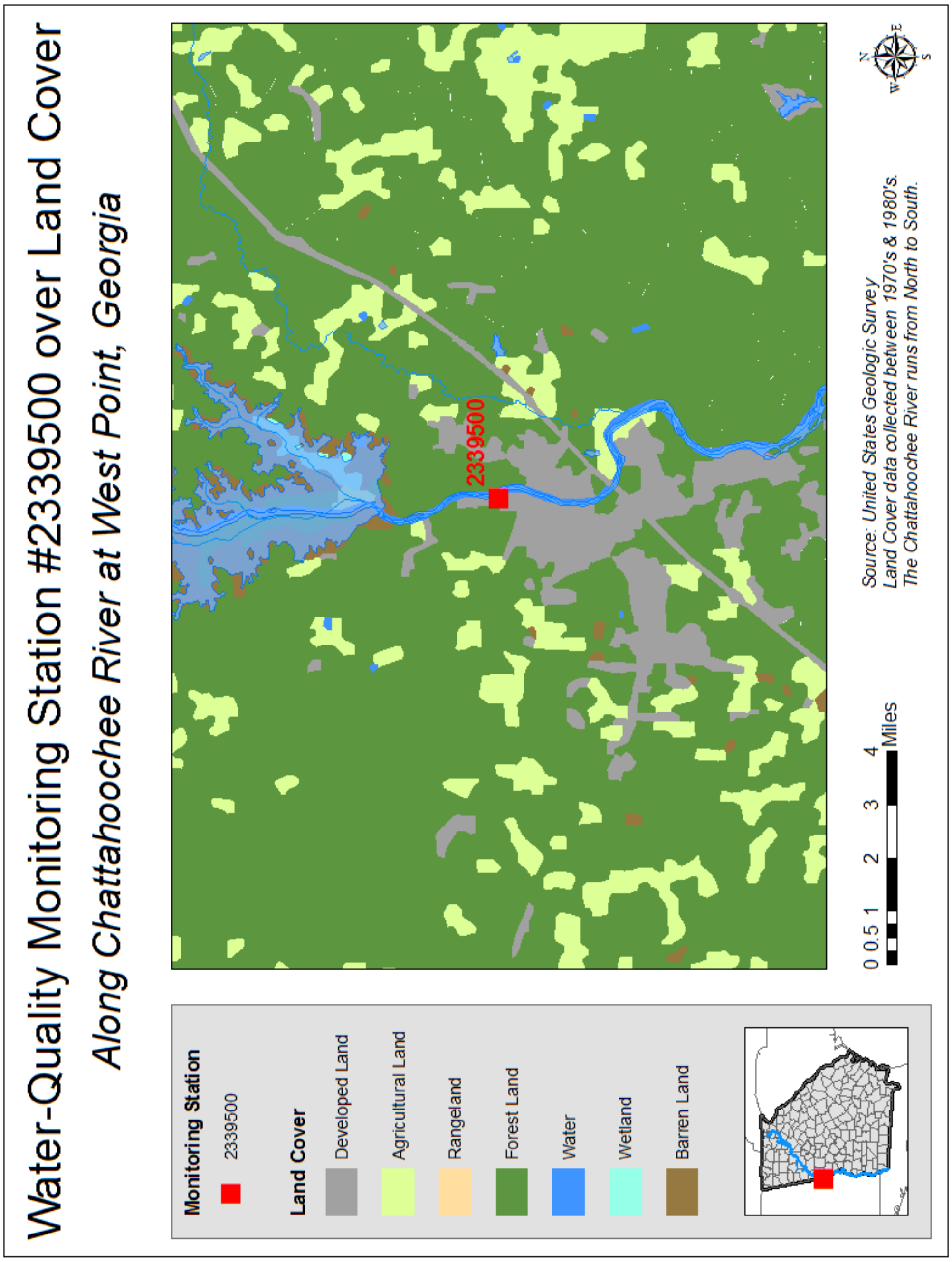

Figure 9: Sampling Station along Chattahoochee River at West Point, GA.

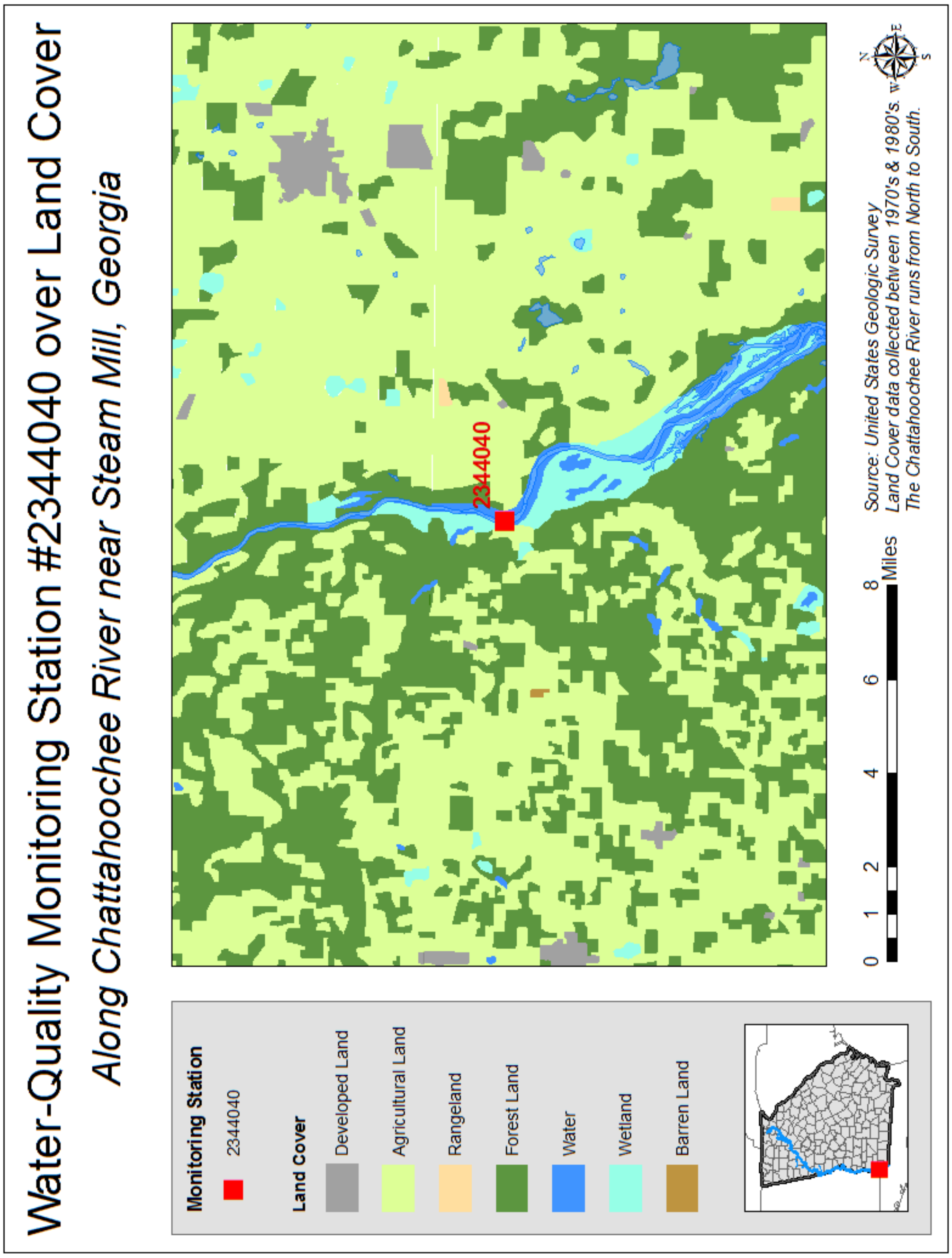

Figure 10: Sampling Station along Chattahoochee River at Steam Mill, GA.

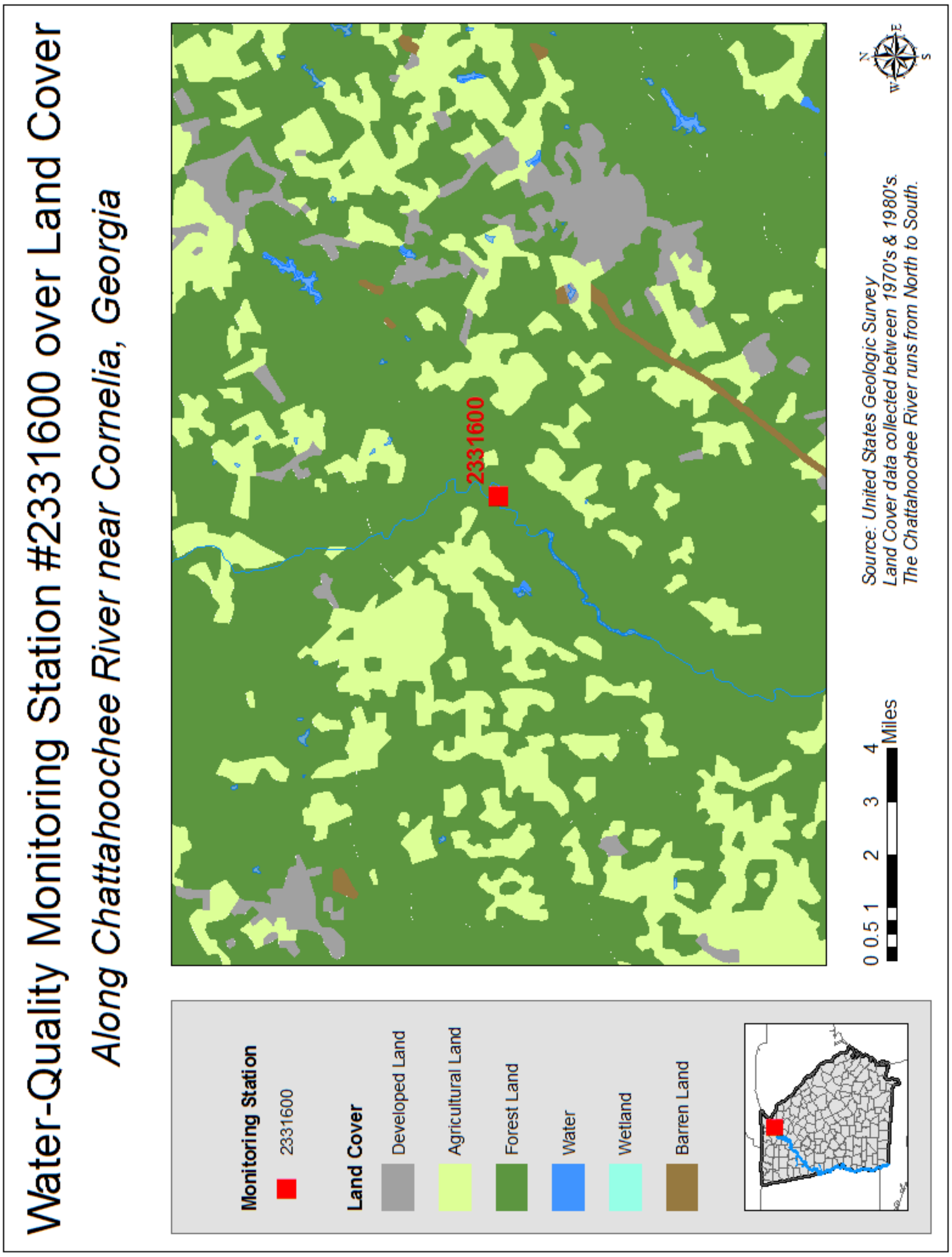

Figure 11: Sampling Station along Chattahoochee River, Cornelia, GA.

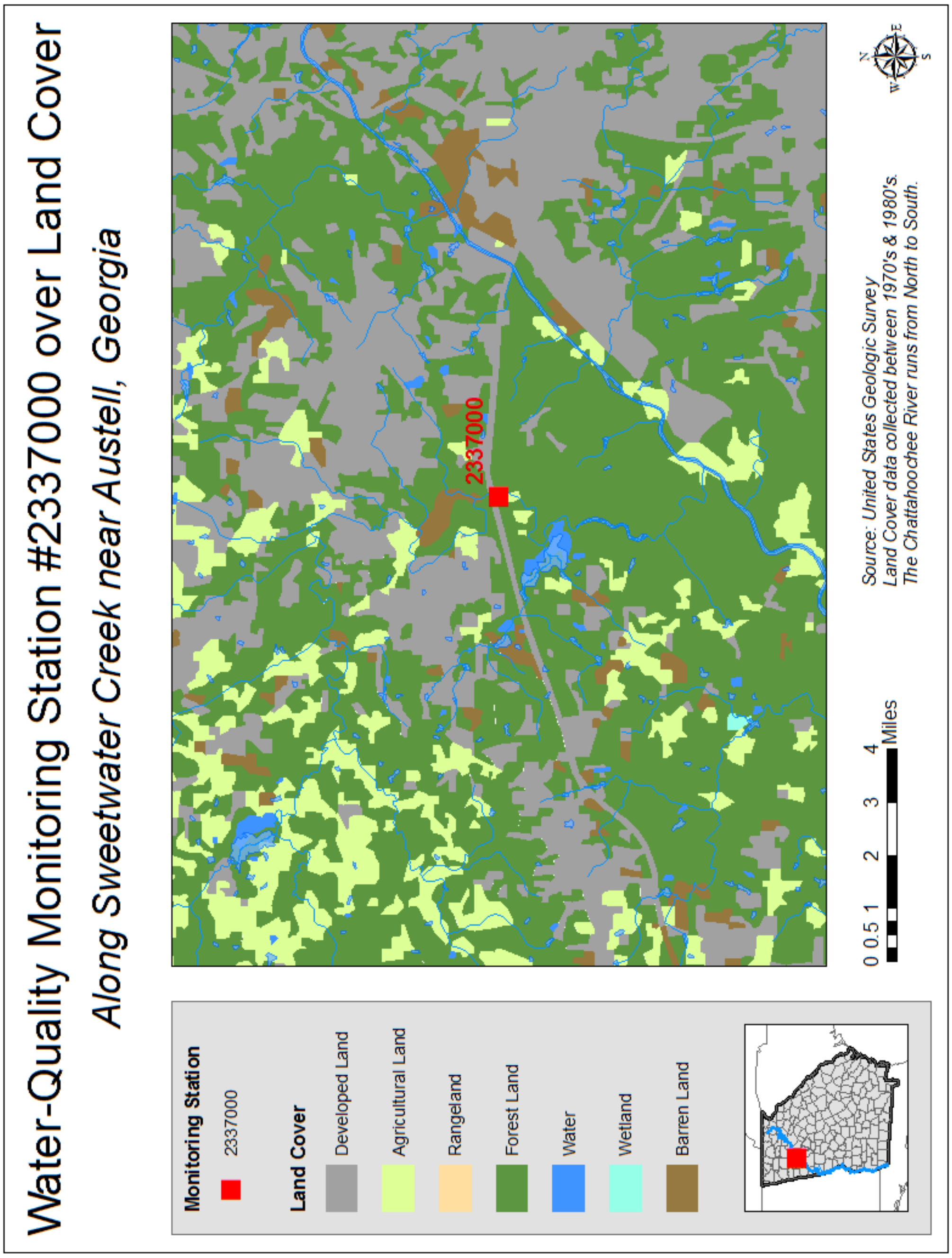

Figure 12: Sampling Station along Sweetwater Creek at Austell, GA.

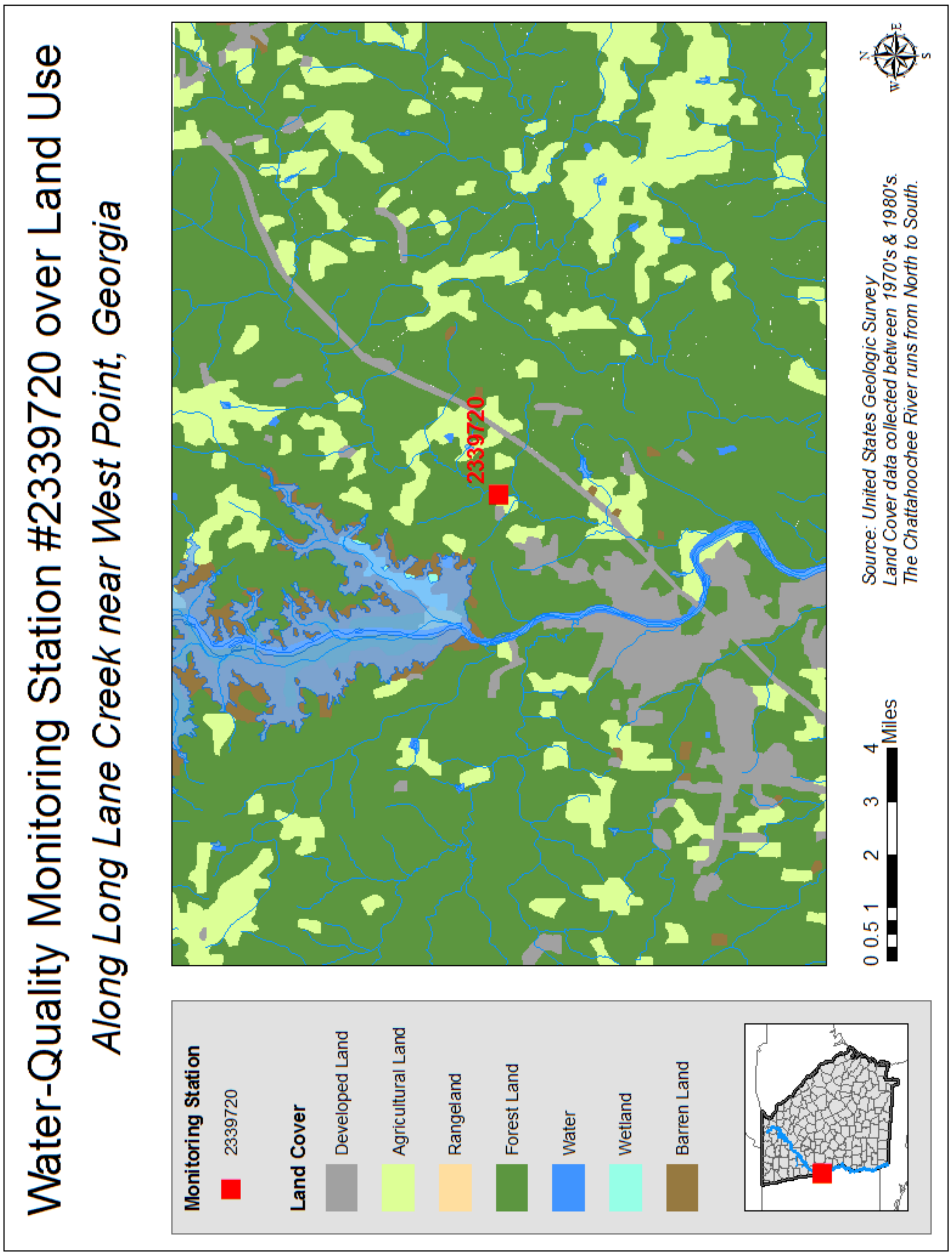

Figure 13: Sampling Station along Long Lane Creek at West Point, GA.

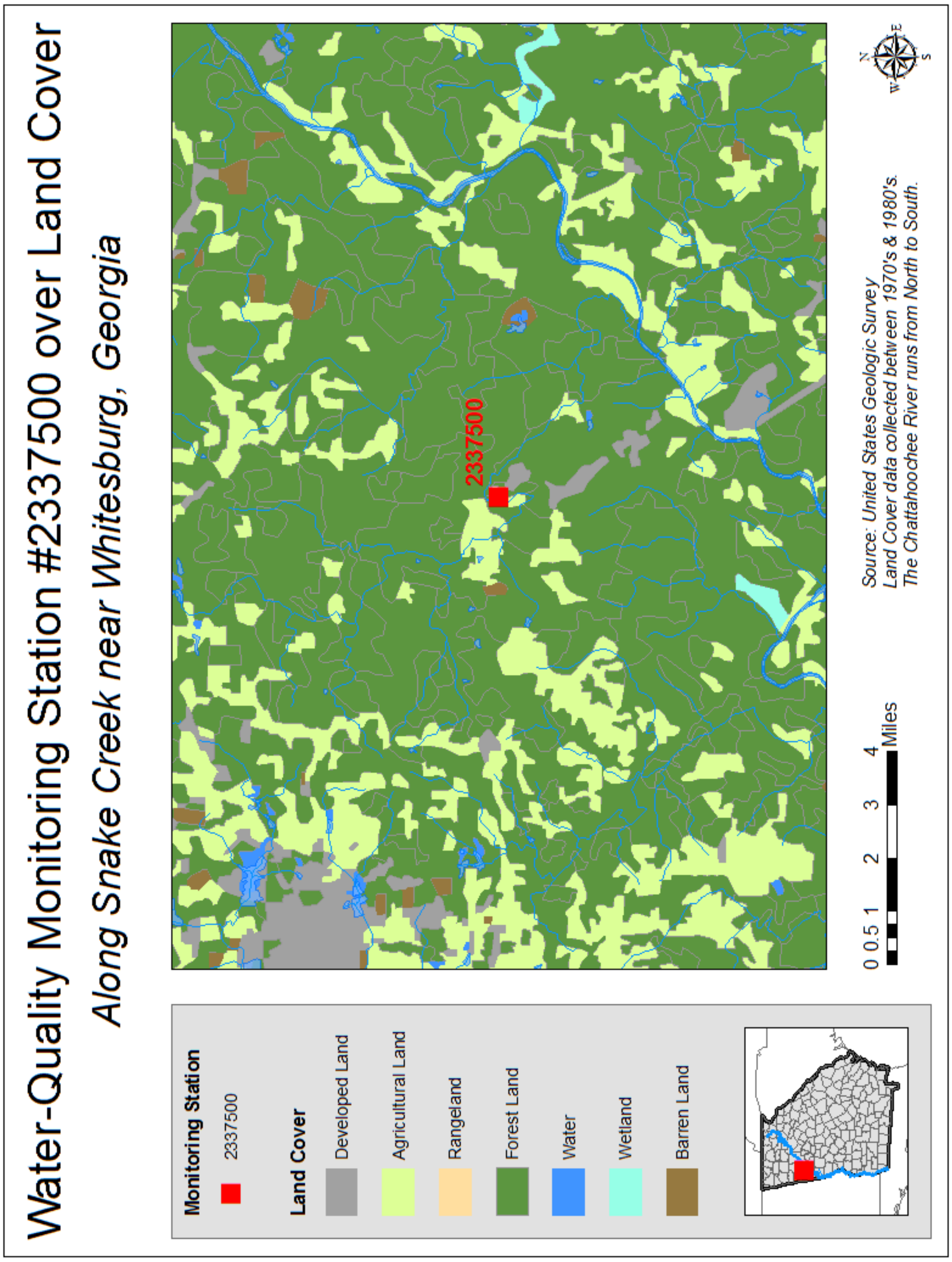

Figure 14: Sampling Station along Snake Creek at Whitesburg, GA.

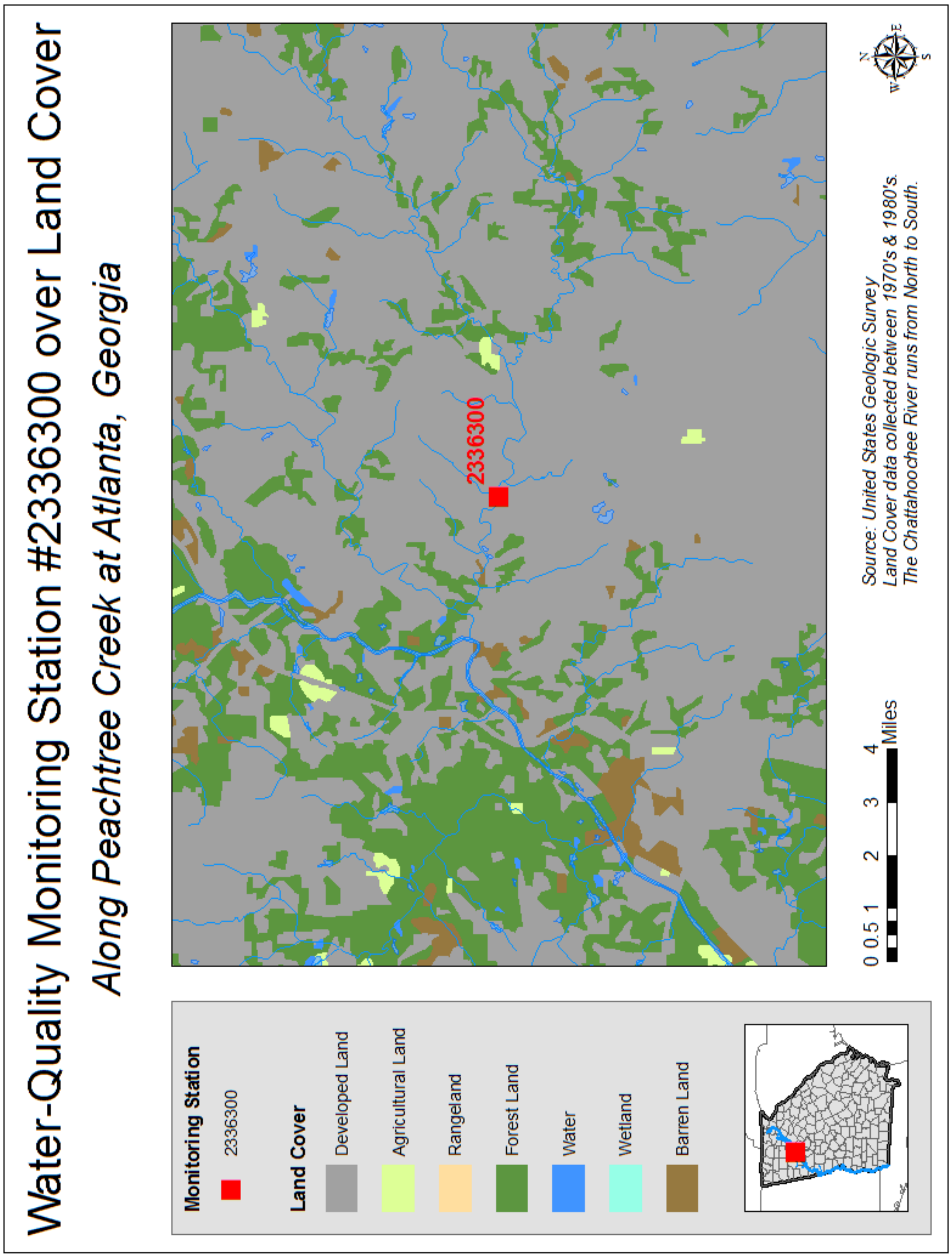

Figure 15: Sampling Station along Peachtree Creek at Atlanta, GA.

Description of Research Data

The water quality variable data was initially collected by the USGS as primary data. Each sampling station in the basin collected all water quality data for the variables used in the research. The GIS data was provided by the USGS. Global Positioning System (GPS) points determined the geographic locations of the sampling stations. The data is collected and recorded by USGS personnel and the results are transmitted via telephone or satellite to the USGS database (USGS 2005). The results from these sampling stations were made available on the USGS website for general knowledge and research. The parameters to decide which sampling stations to include in the study were geographic location in the Chattahoochee River Basin and availability of data for all four water quality variables (Fecal Coliform, Nitrites, Phosphorus, and Dissolved Oxygen) within the research period from 1985 to 2010 [legislation of The Act began in 1989] and a minimum of 250 observations for each station. Once the parameters were set, all sampling stations appropriate for the research were analyzed by querying the USGS web site.

Data not used included stations with fewer than 250 total observations and stations that had not measured all four water quality variables within the 1985 – 2010 research period. In this Chattahoochee River Basin research, no adjustments were made to the data. The data is raw and unadjusted for season, discharge, additional legislation or water quality improvement projects.

Statistical Methods

In order to make the water quality assessments, the first statistical data analysis was determining the annual mean of each water quality variable every year between 1985 and 2010. For each of the water sampling stations, all test results for each of the four variables for each year were added together and divided the sum by the number of annual observations. This statistical process provided the annual mean for each sampling station. Each mean gave a figure that would represent one year in a line chart. The figures were shown in line graph form and were interpreted as annual representative figures for analysis of change within the study period.

To test for changes in water quality, the researcher employed two statistical tests. For the variables that were normally distributed, the Student's T-Test provided a way to see if the mean or average values of the water quality variables before the implementation of riparian buffers were significantly different from the means of water quality variables after the buffers were required.

The second statistical method used for the research was the Mann-Whitney U-Test for variables that did not meet normal distribution requirements. The U-Test was used to see if there was a statistically significant difference between the means of water quality variables for before the riparian buffers (1985 to 1989) as compared to the years after (1990 to 2010) (Ebdon 1985). Specifically, the tests were implemented to find if there was a hypothesized increase in dissolved oxygen after 1989 and a decrease in fecal coliform, nitrites, and phosphorus after 1989.

Chapter 5
The Results

The contaminants analyzed in the Chattahoochee River Basin research are listed by the EPA as contaminants found in drinking water throughout the United States. The research analysis includes line charts depicting the annual trend of the four water quality variables. The study used the Mann-Whitney U-Test and the Student's t-Test (Table 1) to determine if there was a statistical significance and difference between the water quality variable levels before the riparian buffers were implemented in 1989 and the years after. For all four water quality variables, at all twelve sampling stations, every sample value taken between 1985 and 1989 (x) represents water quality before the riparian buffers are installed.

All sample values for between 1990 and 2010 (y) represents water quality after the riparian buffers are installed. Both tests were performed to test for a significant difference between the values x and y. The null hypothesis is that the there will be no difference between x and y. The alternative hypotheses are ($x > y$) for nitrites, phosphorus, and fecal coliform as the research expects to find a decrease in these variables and in the case of dissolved oxygen ($x < y$) as the research expects to find an increase in dissolved oxygen levels.

Table 1. **Statistical Analysis of Water Quality Variables, the Student's t-Test was used for parametric data and the Mann-Whitney U-Test was used for non-parametric data.**

Student's T-Test

Water Quality Variable	*Degrees of* Freedom	*t Critical – (one-tailed test)* (significance .05)	*t* statistic	*p* value	*Mean* *(1985-1989)*	*Mean* *(1990-2010)*
Dissolved Oxygen	1765	1.65	-3.43	0.0003	8.1	8.5
Nitrites	1458	1.65	1.24	0.1079	.75	.70

* The t-statistic value was less than the critical t value; therefore the HA was accepted for dissolved oxygen and fail to reject the HA for nitrites.

Mann-Whitney U-Test

Water Quality Variable	*U Score* *(1985-1989)*	*U Score* *(1990-2010)*	*Z* score	*p* value	*Mean* 1985-1989	*Mean* 1990-2010
Phosphorus	607104	1067459	10.29	.0003	.32	.12
Fecal Coliform	367814	606036	2.81	0.0025	7626	3450

Table 1: Student's T-Test & Mann Whitney U-Test for statistical significance.

The annual mean for all four water quality variables was analyzed in line charts. Furthermore, there was a mean of the annual means for each of the four variables. The mean of means represents the overall trend of water quality variables before and after the riparian buffer installation in 1989. Dissolved oxygen (Figure 16) was the first variable for analysis. The EPA set the ideal standard for dissolved oxygen at 8.0 mg/L where any sample result greater than 8.0 mg/L is considered favorable for drinking water and the natural environment. After 1989, the overall trend of those sampling stations found below the 8.0 mg/L before 1989 found improvement of water quality to be above the 8.0 mg/L ideal standard. When the Student's T-Test was performed for dissolved oxygen, the null hypothesis was rejected (Table 1).

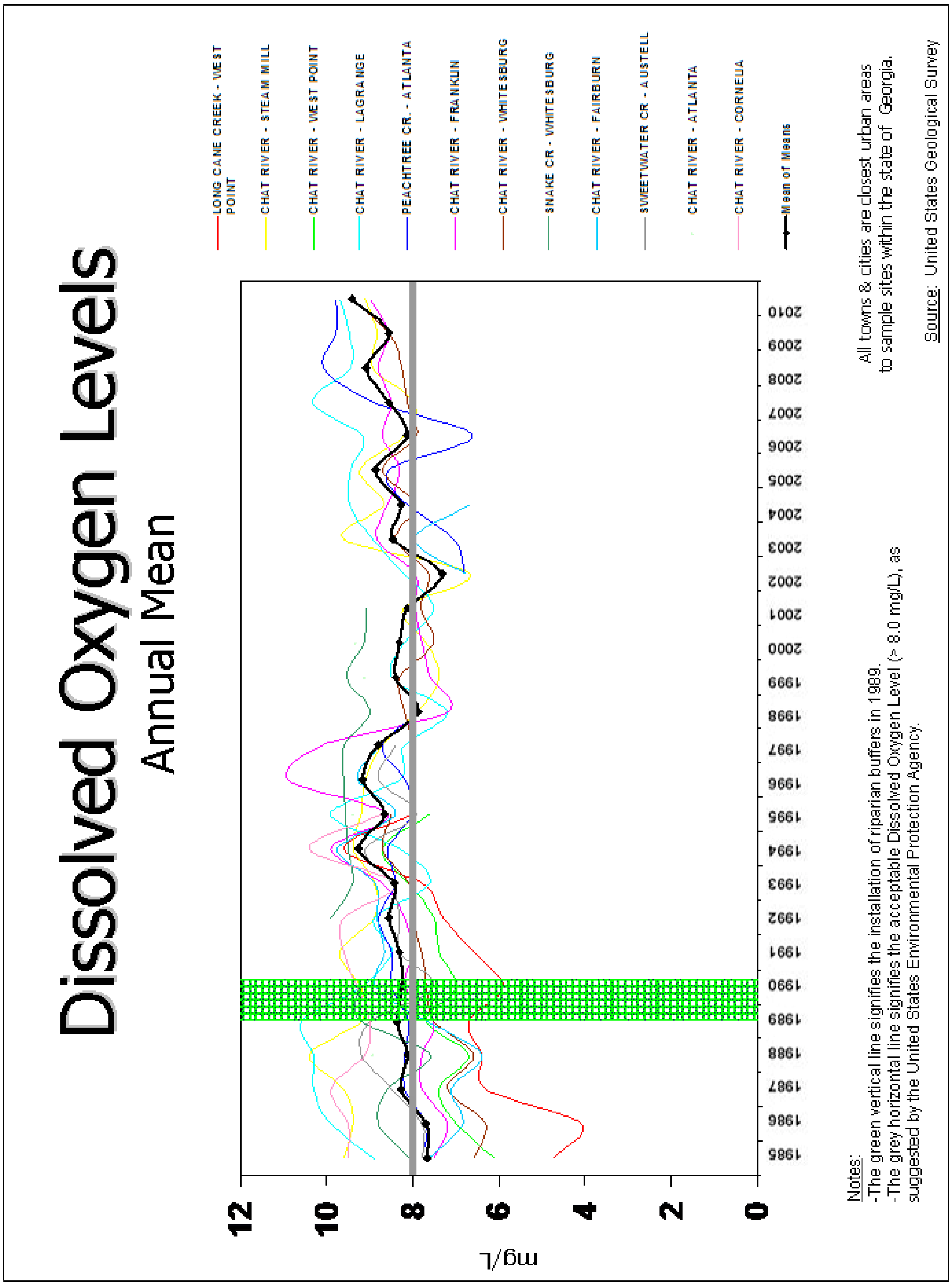

Figure 16: Dissolved Oxygen Levels - Annual Means 1985 - 2010.

The annual mean line chart for dissolved oxygen shows that 71% (five out of seven) of the sampling stations found below the EPA's ideal limit before 1989 were found above the limit after 1990, which shows a statistically significant increase in dissolved oxygen due to the riparian buffer installation.

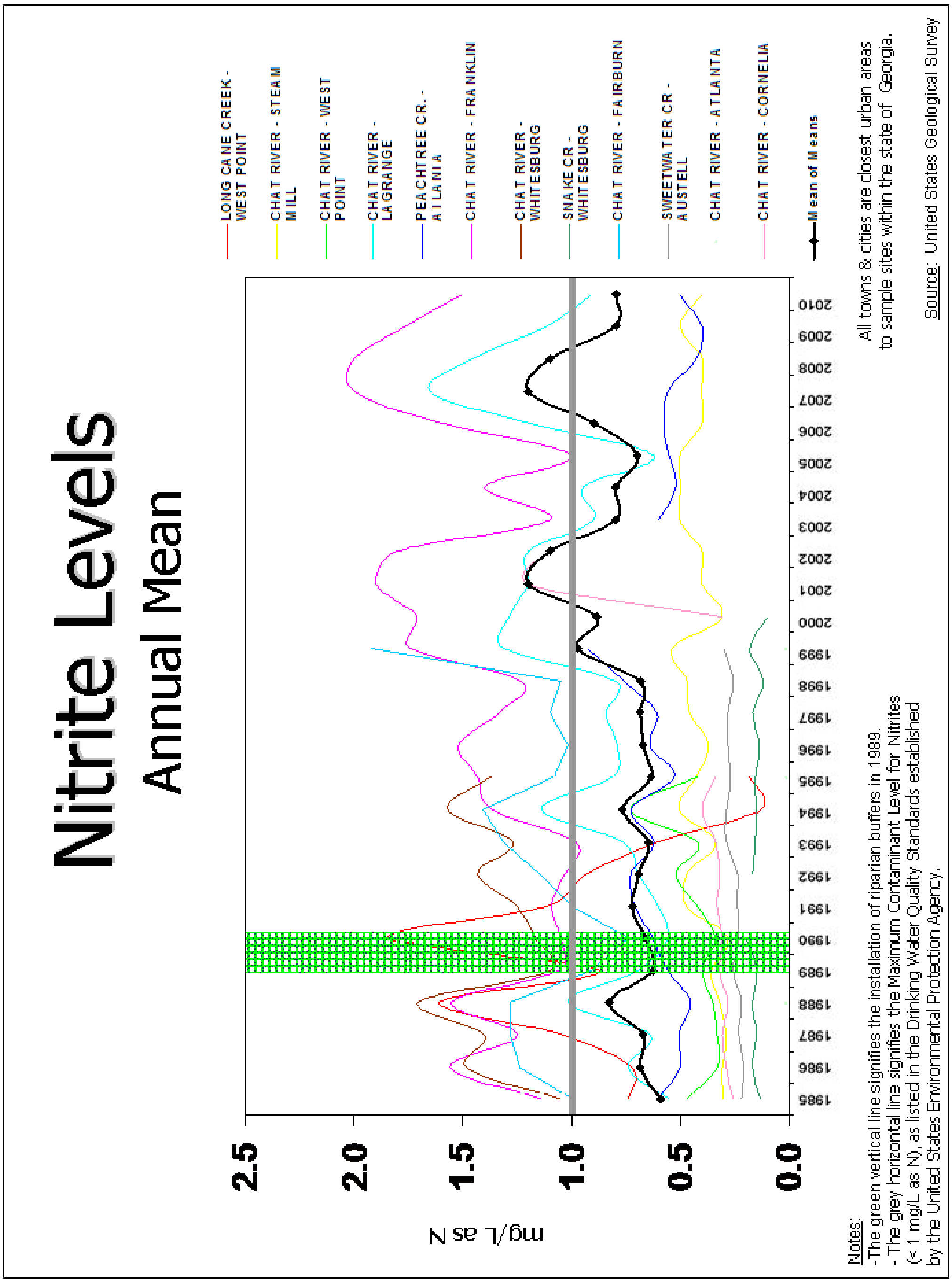

Figure 17: Nitrite Levels - Annual Means 1985 - 2010.

The second variable for analysis was nitrites (Figure 17). The ideal limit set by the EPA for nitrites is 1 mg/L as N. Nine out of the twelve (75%) sample stations found a general increase of nitrite levels starting from the beginning of the study period in 1985 to the end of the study period in 2010. This trend goes against the research hypothesis. General analysis shows that the riparian buffers showed little influence on nitrite levels with one exception, which was Long Crane Creek near West Point, Georgia.

This station showed a general increase in nitrites leading up to 1989, but had a sharp decline in 1990 and ending far below the EPA's limit in the 2010 data. The annual means chart for nitrites shows several sampling stations with a steady increase in nitrites before and after the riparian buffers were put into place in 1989. When the Student's t-Test was performed for nitrites, the null hypothesis was not rejected. Possible explanations for this trend include the influence of agricultural fertilizers, decomposition of organisms, excessive amounts of manure, suburbanization and urbanization of the watershed, and household wastewater (www.epa.gov. 2005).

The variable phosphorus (Figure 18) shows a general decrease after the installation of the riparian buffers. The EPA set the maximum contaminant level for phosphorus at 0.1 mg/L. The five-year time period before 1989 shows a fluctuation in phosphorus levels in five particular stations. General analysis shows that the riparian buffers had a significant influence on phosphorus levels. Five of the twelve (42%) of the sampling stations were above this level before 1989, and the five stations all showed a decrease that started in 1989. The other seven stations were below the 0.1 mg/L standard at the beginning of the research period to the end of the research period. The U score for phosphorus for the 1985 – 1989 data was 607,104 and for the 1990 – 2010 data was 1,067,459. The z-score was

10.29 and the null hypothesis was rejected (Table 1). The significance level or p-value was measured at 0.003, which is highly significant. Possible phosphorus sources include agricultural fertilizers, manure, and runoff (www.epa.gov. 2005).

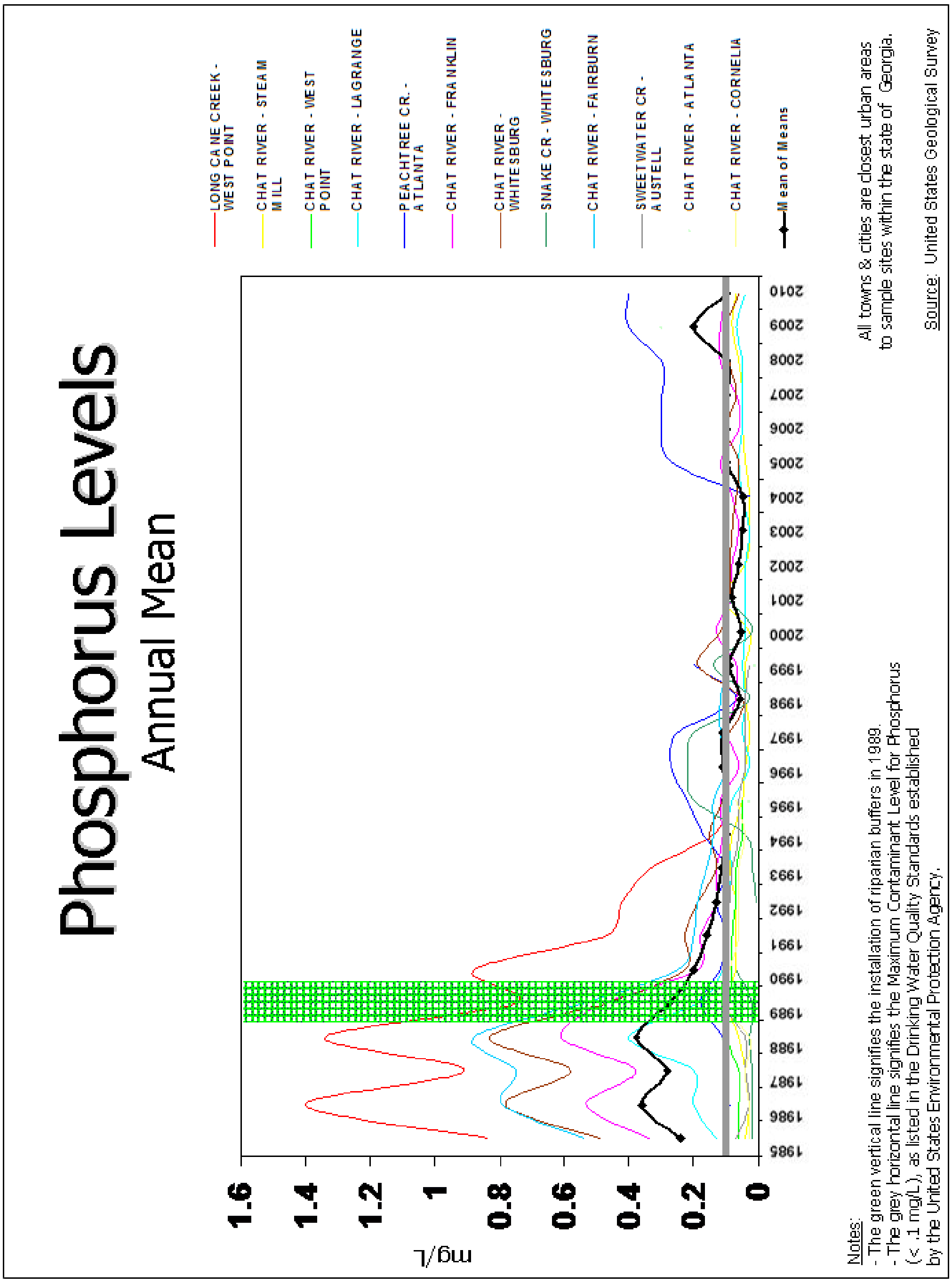

Figure 18: Phosphorus Levels - Annual Means 1985 - 2010.

The final water quality variable analyzed was fecal coliform (Figure 19). The EPA set the ideal maximum contaminant level for fecal coliform at 0 MPN/100 mL or a complete absence of fecal coliform within the Chattahoochee River Basin. The sampling site at Snake Creek near Whitesburg, GA is the only site without any fecal coliform tests performed during the twenty-five-year research period. Samples only from Peachtree Creek near Atlanta, GA were collected after 2000 and it is the most evident outlier (Figure 15). The annual mean of Fecal Coliform at Peachtree Creek after 2000 is also the annual means of means of Fecal Coliform after 2000.

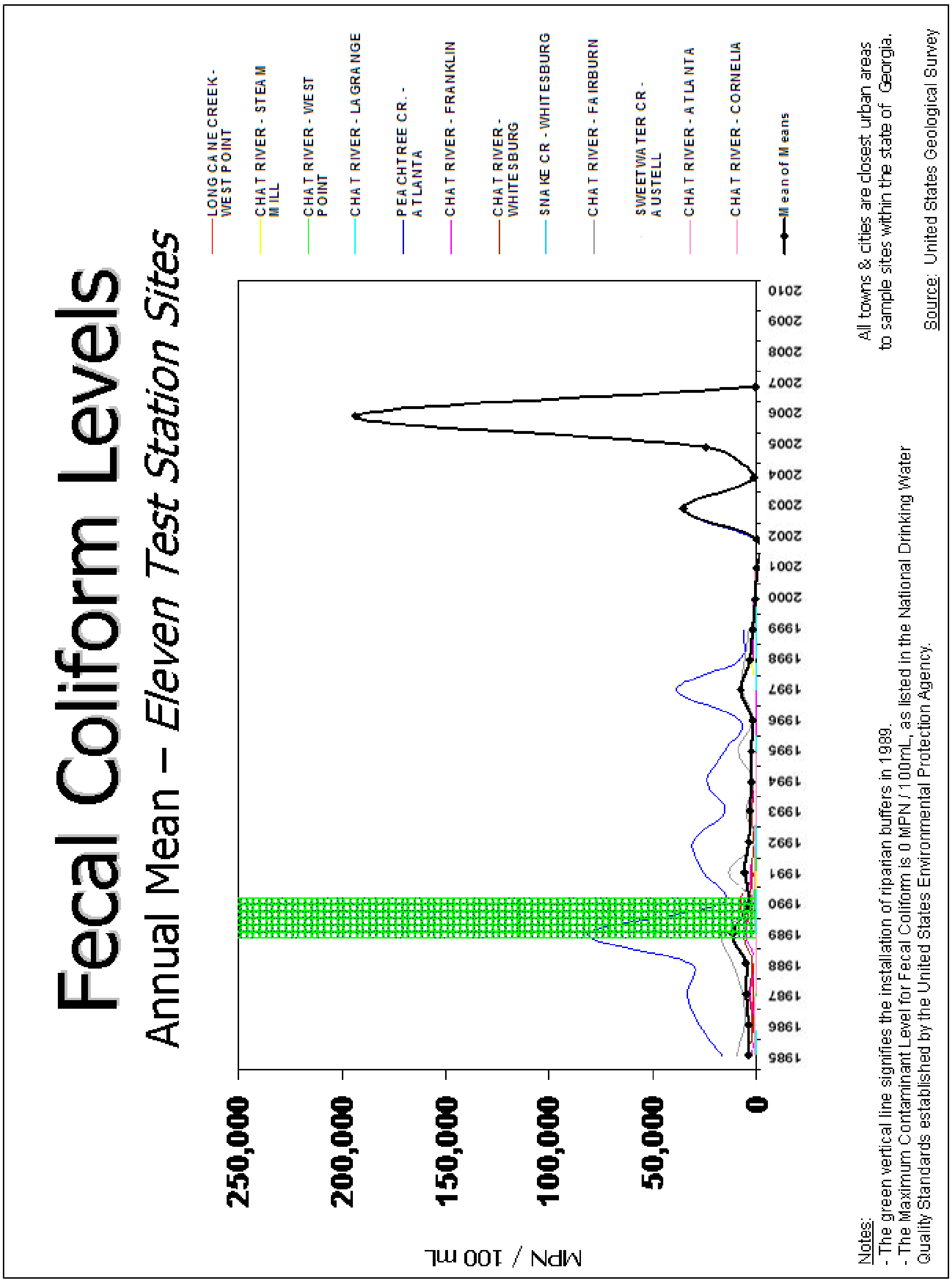

Figure 19: Fecal Coliform Levels - Annual Means 1985 - 2010.

Within the research period, the fecal coliform level for Peachtree Creek peaks at 81,660 MPN/100mL in 1989, well above any other sampling site. A possible explanation for the levels found at the Peachtree Creek sampling station include its geographic position which is well within an urban area. There are no other land use or land types for over a mile upstream from the sampling site location. The fecal coliform levels at Peachtree Creek were far greater than the other sampling stations so a second chart showing annual fecal coliform levels without this station (Figure 20) was added to show the 1985 to 2000 trends of the other ten sampling station sites in more detail.

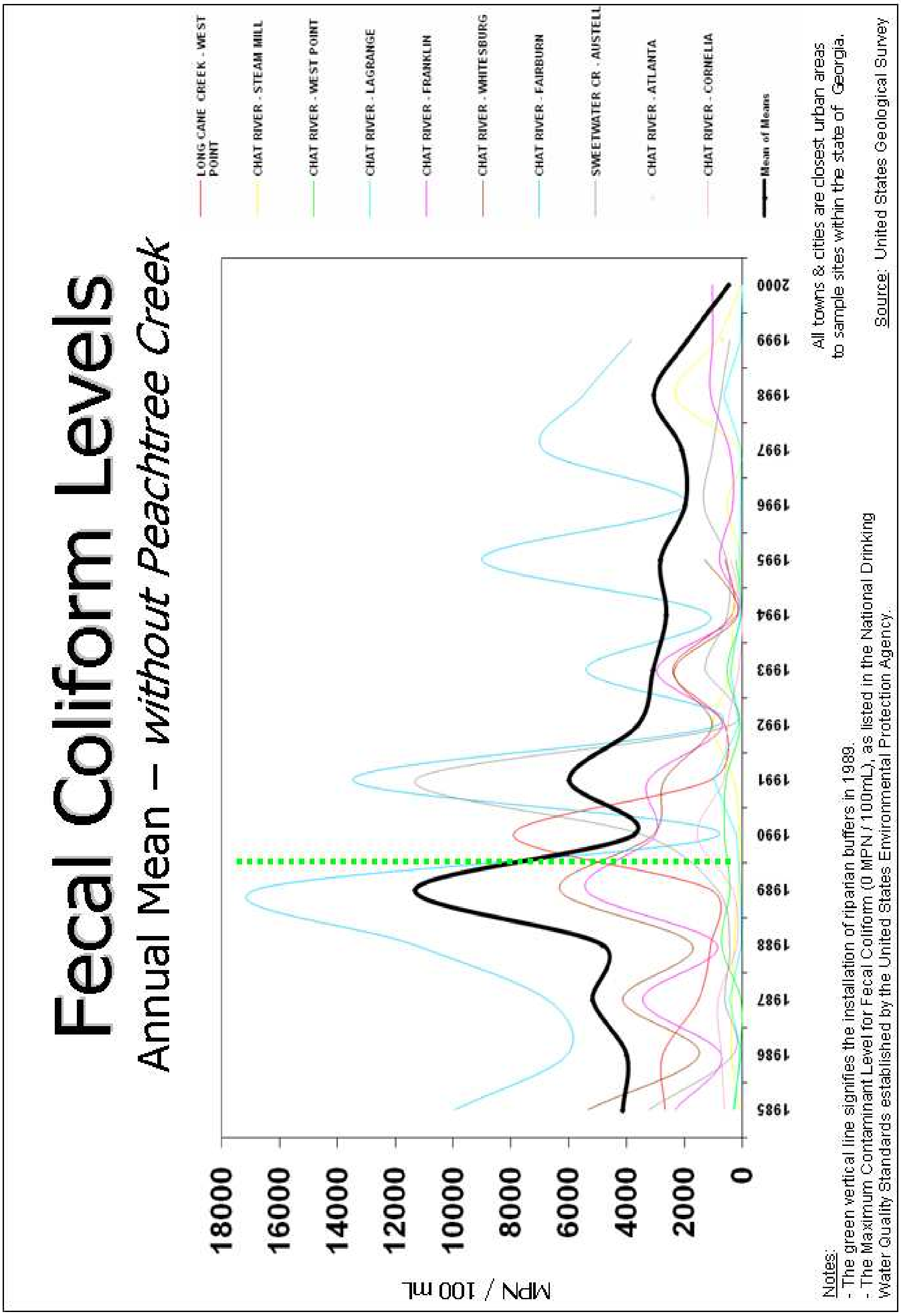

Figure 20: Fecal Coliform Levels - Annual Means 1985 - 2000.

Each of the eleven sample stations show fluctuating increases and decreases in fecal coliform after the 1989 installation of riparian buffers. The fluctuation is possibly due to flooding from excessive rain, which extracts contaminants that are embedded in the adjacent stream banks. The amount of fecal coliform found in an urban area is due to several possible sources including an excess of human waste, sewage overflow, runoff, or septic tank failure (www.epa.gov. 2005). When the U-Test was performed for fecal coliform, the U score for 1985 - 1989 was 367,814 and the U score for 1990 – 2010 was 606,035 and the z-score was 2.81. The mean value of fecal coliform before riparian buffers were implemented was 7626 that is more than twice the value of 3450 after the buffer. The null hypothesis was rejected and the significance level was 0.002473 [at the 0.05 level], which is highly significant.

Overall, there are two sampling stations that stand out. Long Cane Creek near West Point, GA has high levels of all contaminants and Cornelia has consistently met EPA water quality standards. Analysis of all water quality variables sampled at Long Cane Creek near West Point (Figure 9), Georgia have high levels of phosphorus, nitrites, and fecal coliform, and a low dissolved oxygen level before 1989. The years following 1989 found the site's phosphorus and nitrite levels to be below the EPA water quality standards. The site is found in an urban area and its high contaminant level may be due to runoff. Furthermore, the site has a low dissolved oxygen level possibly due to the lack of wild vegetation growing in the riparian zones.

The sampling station along the Chattahoochee River near Cornelia, Georgia (Figure 10) was found to have levels of phosphorus and nitrites levels consistently below the EPA drinking water quality standards throughout the twenty-five-year research period. The site

also had a comparatively low level of fecal coliform and was consistently above the EPA drinking water quality standard for dissolved oxygen during the research period. The Cornelia site is located upstream on the Chattahoochee River, northeast of the metropolitan Atlanta region. GIS analysis found the site to be well within a forested region without any agricultural or urban influence on the river for over 5,500 meters (nearly three miles).

Chapter 6
Conclusions of the Study

The Chattahoochee River Basin research analyzed the impact of water quality variable levels due to the presence of riparian buffers. The Chattahoochee River is a water supply for millions of people in the metropolitan Atlanta region. The research used twelve USGS sampling stations within the basin that measured phosphorus, nitrites, dissolved oxygen, and fecal coliform. Line charts showed overall water quality variable trends within the 1985 to 2010 research period. The statistical tests showed a statistically significant increase of dissolved oxygen after the 1989 installation of riparian buffers, a statistically significant decrease of phosphorus and fecal coliform and a decrease of nitrite concentrations that was not statistically significant.

The analysis of water quality trends after 1989 found a general increase of dissolved oxygen and a general decrease of phosphorus, nitrites, and fecal coliform. The increase of dissolved oxygen may be related to enactment of legislation requiring all riparian buffers to allow natural vegetation to grow. The subsequent vegetation provides canopy cover, which decreases the temperature of the water and increases the amount of oxygen present in the water below.

Analysis of the geographic location of the sampling stations found in urban or agricultural areas had a higher level of nitrites, fecal coliform and phosphorus. The contaminant origins include runoff, organic feces and various agricultural practices in riparian zones. The Georgia Erosion and Sedimentation Act of 1975 allows most

agricultural practices to remain even when they are adjacent to a state water way. It is possible that greater restriction to the agricultural section of the act may find a decrease in contaminants in those areas.

The Chattahoochee River Basin research experienced three limitations. The first limitation is the number of sampling stations used for the research. The data for the research came from twelve sampling stations. An increase in the number of sampling stations may better represent the Chattahoochee River Basin. A second limitation is the time span of the research period. Additional years prior to 1985 may provide a suitable assessment of the change of water quality variable levels leading up to the implementation of the act in 1989. The third limitation is the inconsistency of the USGS sampling station data. Some sampling stations had an inconsistent number of samples taken on an annual basis.

The Chattahoochee River Basin research yields two suggestions for further research in the future. The first suggestion is the analysis of more water quality variables beyond the four used in this study. The EPA tests for over eighty water quality variables and the collection of additional water quality variables may provide a more thorough analysis of overall water quality within the basin. A second suggestion is a more focused research area. The research done at a county level, municipal level, or at an individual state water-level may provide a more detailed analysis of the impact that the riparian buffers have on the four water quality variable levels.

A majority of the literature reviewed for the Chattahoochee River Basin research focused on water quality variables, riparian buffers and the use of statistical methods to find any significant changes in the data. The design of the research was modeled after studies

similar to the Chattahoochee River Basin research. As in several past studies, the choice of research within the Chattahoochee River Basin was made for its importance in providing drinking water for a large population in Georgia. Unlike much of the reviewed literature, the variable data was analyzed relative to the implementation of the Georgia Erosion and Sedimentation Act of 1975, which required the installation of riparian buffers around all state waters.

Many of the studies assessed for the Chattahoochee River Basin research, which focused on the use of riparian buffers, had successful results. The success of the use of riparian buffers is defined by the reduction of water contaminants, stronger stream banks, and a decrease in erosion. The results eventually provided the public with healthier drinking water as opposed to the time before the riparian buffers were put into place. The natural environment also benefits from the buffers, as shown in the quality of the water they rely on for life. The benefits include lower water temperature, an increase in the level of oxygen present in the water, and overall cleanliness. The literature that focused on this kind of research found that riparian vegetation had greatly assisted in accomplishing these environmental goals. The Chattahoochee River Basin research focused on riparian buffers and the vegetation that was allowed to grow in these zones provided a statistically significant increase in dissolved oxygen after the Georgia Erosion and Sedimentation Act of 1975 was implemented in 1989, and a statistically significant decrease in phosphorus and fecal coliform. Furthermore, although statistically insignificant, analysis of nitrite levels found a noticeable decrease after 1989.

There are very little, if any, riparian buffer studies that are long-term. There is a lack of analyses of the effects of riparian buffers that span many decades. Riparian buffers may

not be able to completely cleanse an area of all contaminants. Furthermore, the ten years of post-riparian buffer analysis in the Chattahoochee River Basin research is not a sufficient amount of time to find if a riparian buffer can achieve cleanliness, as the process may take several decades. It is clear that the riparian buffers have already had a tremendous positive impact for the Chattahoochee River Basin. The presence of the riparian buffer has an effect on the water it surrounds and the allowance for a riparian zone to return to its normal state can only benefit society and our natural environment.

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